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In Situ Bioremediation Predesign Operations Work Plan Test Area North, Operable Unit 1-07B

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EXECUTIVE SUMMARY

This Operable Unit (OU) 1-07B Predesign Operations Work Plan addresses operation and maintenance of the OU 1-07B In Situ Bioremediation (ISB) system, from May 1, 2001 through implementation of the Remedial Design/Remedial Action Work Plan (RD/RA WP). Activities addressed in this work plan include:

- Beginning scheduled ISB Predesign Operations in May 2001 and continuing through spring 2002. This phase consists of continued ISB system operations, including groundwater monitoring, while investigating the potential for increasing the cost-effectiveness of trichloroethene dechlorination.

- Beginning Predesign Phase III, if determined to be necessary. This Phase will consist of lactate injection in wells Technical Support Facility (TSF)-05 and Test Area North (TAN)-37 (at a depth of about 230 feet) to evaluate redistribution of electron donor. Additionally, alternative electron donors may be evaluated during this phase.

- Maintaining the Air Stripper Treatment Unit in a standby mode (operational but not operating) for the duration of ISB Predesign Operations.

- Decontaminating and dismantling and deactivating the Groundwater Treatment Facility.

- Performing a conservative tracer test in FY 2002.

This work plan replaces the ISB Field Evaluation Work Plan as the controlling document for operating the OU 1-07B ISB system, prior to implementing ISB remediation scheduled for spring 2002. At that time, the ISB RD/RA WP will become the controlling document for subsequent operations. Significant changes from the Field Evaluation Work Plan described in this work plan include reducing the monitoring frequencies for selected parameters, maintaining the Air Stripper Treatment Unit in standby mode after April 30, 2001, and reducing the frequency of lactate injection.

A cost estimate for Predesign Operations is provided. A supporting document, the OU 1-07B Predesign Operations Sampling and Analysis Plan, (INEEL 2000c) was submitted as a separate report.

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ACRONYMS

ARD	anaerobic reductive dechlorination
ASTU	Air Stripper Treatment Unit
D&D&D	decontamination and dismantlement and deactivation
DOE	Department of Energy
DQO	Data Quality Objectives
EPA	Environmental Protection Agency
FDR	Field Demonstration Report
FEWP	Field Evaluation Work Plan
FY	fiscal year
GWTF	Groundwater Treatment Facility
HASP	Health and Safety Plan
INEEL	Idaho National Engineering and Environmental Laboratory
ISB	in situ bioremediation
NPTF	New Pump and Treat Facility
OU	operable unit
PDP-I	Predesign Phase I
PDP-II	Predesign Phase II
PDP-III	Predesign Phase III
RT3D	Reactive Transport 3-Dimensional
SAP	Sampling and Analysis Plan
SVOC	semi-volatile organic compounds
TAN	Test Area North
TCE	trichloroethene
TPR	technical procedure
TSF	Technical Support Facility
VOC	volatile organic compound

In Situ Bioremediation Predesign Operations Work Plan Test Area North, Operable Unit 1-07B

1. INTRODUCTION

This work plan addresses Predesign Operations of the Operable Unit (OU) 1-07B In Situ Bioremediation (ISB) system, from May 1, 2001, through spring 2002. Figure 1-1 shows the sequence of OU 1-07B activities and controlling documents for each. Predesign Operations follows successful completion of the ISB Field Evaluation, and two phases of Predesign Activities; and precedes implementation of the ISB Remedial Design/Remedial Action Work Plan (RD/RA WP). Predesign Phase I (PDP-I) is described in Section 3.3.1, and consisted of monthly groundwater sampling during a period of no electron donor injection. Predesign Phase II (PDP-II) is described in Section 3.3.2, and consisted of renewed electron donor injection and biweekly monitoring at 13 wells.

Activities addressed in this work plan include:

- ISB Predesign Operations, scheduled to begin in May 2001 and continue through Spring 2002. This phase consists of continued ISB system operations and maintenance including groundwater monitoring, while increasing the cost-effectiveness of trichloroethene (TCE) dechlorination to the extent feasible. The scope of these activities is described in the *Field Demonstration Report* (FDR*), Test Area North Final Groundwater Remediation, Operable Unit 1-07B* (Department of Energy [DOE], 2000, Section 5.6.1).

- Predesign Phase III, if determined to be necessary. This phase will consist of lactate injection in Technical Support Facility (TSF)-05 and Test Area North (TAN)-37 (at a depth of about 230 feet) to evaluate the effect of injection location on the spatial distribution of electron donor solution. Additionally, alternative electron donors may be evaluated during this phase. Monitoring will be conducted biweekly at 7 to 13 locations. Scope of this activity is described in the *Enhanced In Situ Bioremediation Field Evaluation Work Plan* (FEWP) (DOE 1998a, Appendix E).

- Maintaining the Air Stripper Treatment Unit (ASTU) in a standby mode (operational but not operating) for the duration of ISB Predesign Operations.

- Decontaminating and dismantling and deactivating the Groundwater Treatment Facility (GWTF).

- Performing a conservative tracer test in FY 2002. The test is described in Appendix A of this work plan.

This work plan is identified as a Federal Facility Agreement and Consent Order (FFA/CO) secondary document in the *Field Demonstration Report, Test Area North Final Groundwater Remediation*, OU 1-07B (DOE 2000). This work plan replaces the ISB Field Evaluation Work Plan (FEWP) (DOE 1998a) as the controlling document for operating the OU 1-07B ISB system, prior to implementing the ISB RD/RA WP scheduled for spring 2002. At that time, the ISB RD/RA WP will become the controlling document for subsequent operations.

A cost estimate for the Predesign Operations period is provided. A supporting document, the OU 1-07B Predesign Operations Sampling and Analysis Plan (SAP) (INEEL 2000c), was submitted as a separate report.

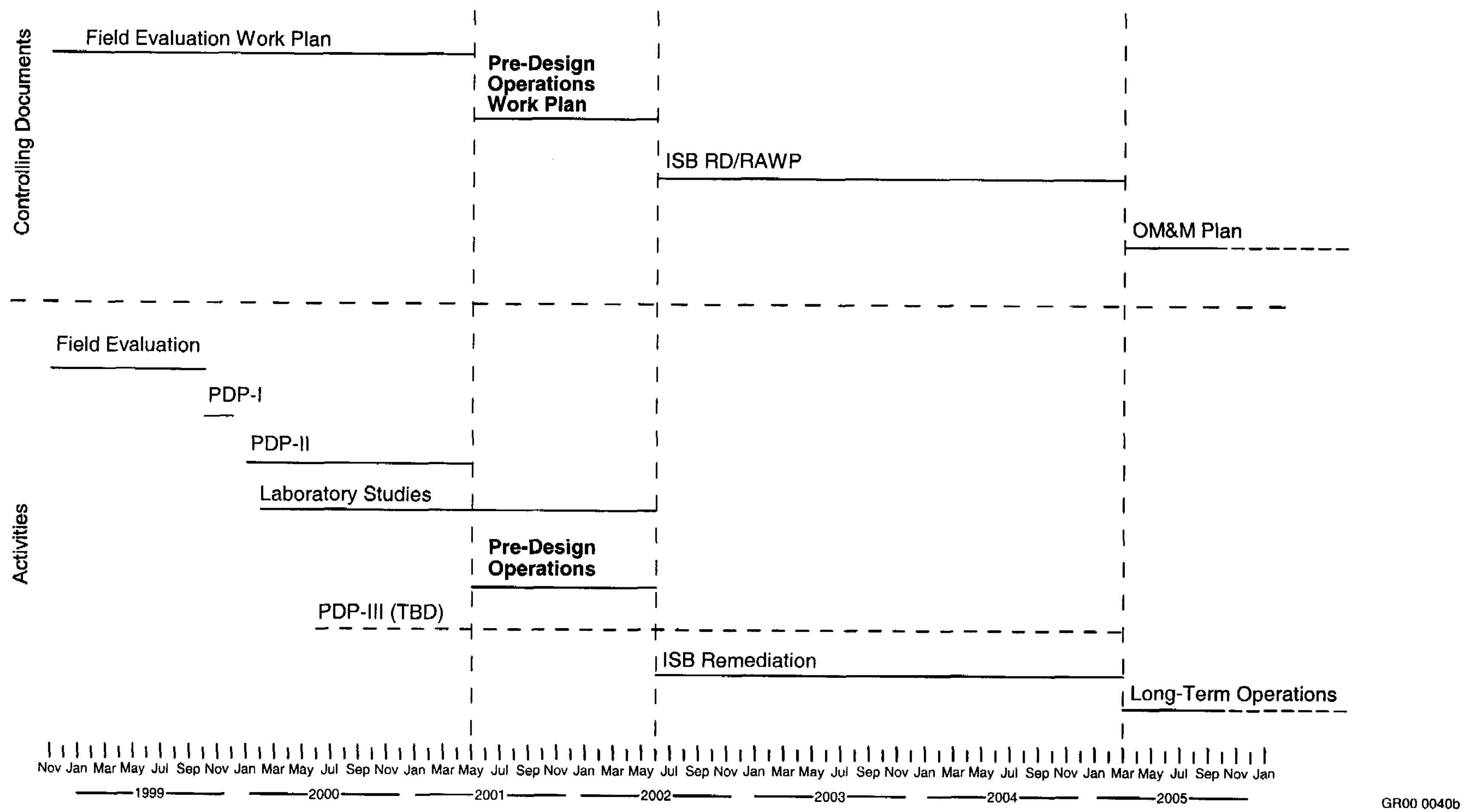


Figure 1-1. OU 1-07B project activities and controlling documents.

2. WORK PLAN OBJECTIVES AND SCOPE

This Section discusses Predesign Operations objectives. Section 5.6.1 of the FDR (DOE 2000) states that the scope of this work plan will include continued ISB system operations; modeling to optimize the final ISB treatment system design and operating strategy; and Predesign Phase III, if necessary.

Specific objectives were defined to address the required scope. Both continued system operations and optimization modeling are focused on increasing the cost-effectiveness of operations; therefore, specific objectives to increase cost-effectiveness are identified for those activities. Objectives for the Predesign Phase III (PDP-III) are defined in DOE (1998a). Table 2-1 shows the specific objectives defined for each element of required scope.

This work plan provides information and implements activities that support these objectives. Additionally, these objectives were used as inputs to the Environmental Protection Agency's (EPA's) is Data Quality Objectives (DQO) process to produce the Predesign Operations SAP prepared to support this work plan. More detail on sampling and analysis is provided in Section 5 of this work plan.

Table 2–1. Specific objectives defined to meet required OU 1-07B Predesign Operations scope.

Required Scope	Specific Objective
• Continued ISB System Operations	A. Continue to operate the ISB System to contain and degrade the OU 1-07B hotspot.
• Continued ISB System Operation • Modeling to optimize the final ISB treatment system design and operating strategy	B. Maximize cost-effectiveness of TCE dechlorination.
• Continued ISB System Operations	C. Optimize sampling frequency and analytes.
• Continued ISB System Operations • PDP-III	D. Determine whether lactate injection results in mobilization of metals, strontium, and/or semi-volatile organic compounds (SVOCs) from the secondary source (defined as an objective for all Predesign Phases in DOE 1998a, Appendix E).
• PDP-III	E. Determine how to distribute electron donor better within the upper part of the aquifer (defined in DOE 1998a, Appendix E, for PDP-III).
• Laboratory Studies	F. Determine the effectiveness of alternative electron donors relative to lactate for sustaining anaerobic reductive dechlorination (ARD) reactions within the aquifer (defined in DOE 1998a, Appendix E, for PDP-III).

3. SUMMARY OF OU 1-07B ISB FIELD ACTIVITIES PERFORMED TO DATE

OU 1-07B ISB field evaluations performed to date are described in detail in DOE (2000), and the three phases of ISB Predesign Phase Activities are described in Appendix E of DOE (1998a). Procedures and results for each are briefly summarized in this section.

3.1 Field Evaluation

The field evaluation included a one-month startup period at the beginning of the field evaluation, which included a conservative tracer test and baseline groundwater sampling and analysis; and a subsequent nine-month groundwater monitoring period, consisting of electron donor injection in TSF-05 and biweekly sampling at 11 wells to evaluate ISB effectiveness. Both are discussed below.

3.1.1 Start-Up Period Tracer Test

Potable water was injected into TSF-05 beginning November 16, 1998, and extracted approximately 500 ft downgradient at TAN-29, as the initial step in creating an ISB treatment cell with an enhanced hydraulic gradient between the two wells. The injection rate at TSF-05 was approximately 20 gpm, while the extraction rate at TAN-29 was approximately 50 gpm. Extracted groundwater was air stripped to remove volatile organic compounds (VOCs) and reinjected in TAN-49. Groundwater was sampled during the start-up period at 11 wells.

During this period a slug of bromide solution, a conservative tracer, was injected into TSF-05, to evaluate the hydraulic communication between TSF-05 and surrounding wells; and to investigate the effect of residual source material on aquifer properties in the vicinity of TSF-05. Approximately 25 kg of bromide was injected into the potable water line in a 32 minute period. Bromide concentrations were monitored in 10 wells, with bromide detected in five wells.

Results of the tracer test showed bromide arrival at all five wells within 150 ft of the injection well and screened in the same interval, indicating good hydraulic communication within the ISB treatment cell. An absence of bromide detection in TAN-26 was interpreted as evidence of horizontal preferential flow paths on the scale of the treatment cell.

Tracer test results were also used to estimate the distribution of residual sludge around TSF-05. Apparent reductions in both effective porosity and longitudinal dispersivity near TSF-05 were used to estimate that residual sludge remains between approximately 50 and 115 ft radially from TSF-05. An apparent transition in effective porosity alone was used to estimate that residual sludge remains between 95 to 100 ft radially from TSF-05.

3.1.2 StartUp Period Baseline Groundwater Monitoring

Groundwater was sampled approximately weekly prior to electron donor injection to determine baseline values for parameters of interest. Analytes included:

- Electron donor (lactate) and metabolites including acetate, propionate, butyrate
- Chloroethenes including tetrachloroethene, trichloroethene, isomers of dichloroethene and vinyl chloride

- Supporting geochemical parameters including carbon dioxide, alkalinity, chloride, ferrous iron, ammonia (as nitrogen), phosphate, nitrate and sulfate

- Tritium, used to assess treatment system effects on the source

- Wellhead parameters measured with a Hydrolab including temperature, pH, oxidation-reduction potential, dissolved oxygen, and specific conductance.

Results of baseline monitoring showed that initial potable water injection generally resulted in a decrease in TCE and tritium concentrations at monitoring wells, apparently due to an upset in the equilibrium between sludge pore water and groundwater advecting through the sludge. Initial electron donor concentrations were nondetections throughout the treatment cell, as expected. Baseline nutrient analyses showed relatively low concentrations of ammonia and phosphate, which could potentially limit cell growth and thereby also limit ARD of TCE.

Baseline monitoring of biological activity indicators including, alkalinity and carbon dioxide, was used to establish initial conditions for by-products of microbial metabolism of lactate. Initial redox conditions within the treatment cell were inferred from concentrations of terminal electron acceptors in microbial metabolism including dissolved oxygen, nitrate, ferrous iron, sulfate, and methane. Initial redox conditions were assessed as nitrate-reducing and intermittently sulfate-reducing near TSF-05 and TAN-25, and weakly reducing to aerobic elsewhere in the treatment cell.

Baseline groundwater quality parameters including temperature, pH, and specific conductance were measured, using a Hydrolab Mini Sonde equipped with a flow-through cell. The dissociation of electron donor solution results in an increase in specific conductance, allowing for rapid detection of lactate at monitoring locations.

3.2 Electron Donor Injection and Groundwater Monitoring Period

Air stripper compliance samples were collected for four consecutive days beginning November 16, 1999, the first day of system operations. Chloroethenes and gross alpha and beta were analyzed in water samples collected from the air stripper influent and effluent to assess compliance with regulatory standards. An air sample was collected from the outlet stack and analyzed for chloroethenes. Compliance samples were collected monthly thereafter.

Sodium lactate, selected as an electron donor for microbial metabolism, was injected into TSF-05 between January 7, 1999 and September 8, 1999. Progressively more dilute solutions were used in an effort to optimize distribution of lactate in the aquifer, since more concentrated solutions were more dense and sank, creating a maximum concentration deeper in the aquifer than desired. Lactate transport was monitored indirectly with the Hydrolab at four wells, using specific conductance as an indicator parameter.

Results of groundwater monitoring were used to develop a conceptual model for biochemical and geochemical processes occurring along the flowpath from TSF-05. The conceptual model is provided in Section 3.2 of DOE (2000) and is not repeated here. The conclusions reached in this period of the study include:

- Electron donor was distributed farther from the point of injection in the deeper portions of the aquifer than in the shallower portions

- Indigenous microbes can use lactate for cell growth and metabolism

- No nutrient limitations, other than electron donor, were observed
- The extent of ARD of TCE is correlated to redox conditions
- Complete dechlorination of TCE to ethene was observed wherever sufficient electron donor was present to promote generation of strongly reducing conditions.

3.3 Predesign Phase Activities

Three phases of fiscal year (FY) 2000 ISB Predesign Activities follow the ISB Field Evaluation and precede the Predesign Operations Period. The results of all Predesign activities will be included as an appendix to the ISB RD/RA WP. Additionally, PDP-I and -II results are incorporated into this work plan to define the electron donor addition strategy to be used during the Predesign Operations period. Each of the three Predesign phases is summarized below.

3.3.1 Predesign Phase I

PDP-I was implemented from October 1999 to January 2000 and consisted of monthly sampling during a period when no lactate was injected. The objectives of this phase were to (1) determine the persistence of electron donor and ARD reactions in the absence of lactate injection; (2) evaluate the efficiency of ARD reactions in the prolonged presence of electron donors other than lactate; and (3) determine whether or not lactate injection results in mobilization of metals, strontium, and/or SVOCs from the secondary source (this objective applies to all predesign phases).

Initial Phase I results indicate that (1) electron donor may persist for six to eight weeks after injection; (2) the efficiency of ARD appears to increase in the absence of frequent lactate injection; and (3) lactate injection may affect metals concentrations, but additional monitoring will be required to determine the extent of any increase.

Data obtained during PDP-I will be combined with data from PDP-II, to determine the required lactate addition frequency and quantity required to sustain ARD of TCE during long-term operations.

3.3.2 Predesign Phase II

PDP-II began in January 2000 and will continue through April 2001. This phase consists of renewed lactate injection in TSF-05 with biweekly monitoring at 13 wells. The objectives of this phase are to: (1) determine the effect of renewed lactate injection, after approximately four months without lactate addition, on ARD efficiency and redox conditions through the treatment cell; (2) determine the travel time of electron donor from Well TSF-05 to Well TAN-37C; (3) optimize lactate addition (quantity and frequency) based on the data collected to meet the Phase I objectives; and (4) determine whether or not lactate injection results in mobilization of metals, strontium, and/or SVOCs from the secondary source (this objective applies to all predesign phases).

The frequency and quantity of lactate injection during this phase will be based on data collected during PDP-I, and on the response of the system to renewed lactate injection. Redox conditions, and electron donor and chloroethene concentrations are being monitored to determine whether or not ARD is proceeding as efficiently as expected. Lactate injection frequency and volume will be varied in an effort to improve system performance and cost effectiveness. Electron donor travel time will be determined by monitoring specific conductance and redox potential at Well TAN-37C. These data will also be used to optimize lactate addition.

3.3.3 Predesign Phase III

PDP-III will be implemented only if determined to be necessary, beginning with lactate injection in TSF-05 and TAN-37 at a depth of about 230 ft. Alternative electron donors may also be evaluated during this phase. This decision will be made based on laboratory study results. Additionally, the Reactive Transport 3-Dimensional (RT3D) (Clements 1998) numerical model is being revised for parallel processor operations to model electron donor distribution and alternate electron donor effectiveness.

Seven to 13 monitoring locations will be sampled biweekly to (1) determine how to better distribute electron donor within the upper part of the aquifer; and (2) determine the effectiveness of alternate electron donors relative to lactate for sustaining ARD reactions within the aquifer. If implemented, these data will be used to optimize electron donor addition.

Predesign Phase III activities will be described in detail in either the final version of this work plan, or in a subsequent Document Action Request. However, no modifications to ISB operations to incorporate PDP-III are planned at this time.

4. PREDESIGN OPERATIONS APPROACH

The overall approach for Predesign Operations is to continue to operate the ISB system, while incorporating changes in system operations and monitoring intended to improve system performance and cost effectiveness. Results of PDP-I and -II were used to define the specific approach to be used to meet these objectives.

This section describes the existing ISB system, including the electron donor addition subsystem, the ASTU subsystem, and the monitoring subsystem, and facility modifications to be implemented as part of Predesign Operations. This section also describes the operations plan for each subsystem for FY 2001 through 2004, and the way this work plan will interface with the ISB RD/RA WP. A conservative tracer test to be performed in FY 2002 is described separately in Appendix A.

4.1 System Description

Section 3 of DOE (1998a) describes the OU 1-07B ISB system. That description is summarized below. Figure 4-1 shows the ISB Field Evaluation Site layout.

4.2 Nutrient Addition Subsystem

4.2.1 Subsystem Components

The existing nutrient addition subsystem components include:

- A system enclosure (Sea Box)
- Piping
- An electric drum pump
- Control valves
- A carbon contactor for chlorine removal.

A schematic flow diagram for this subsystem is provided in Figure 4-2 (FEWP Figure 3-7). The carbon filter will continue to be used to remove residual chlorine from the potable water supply. Biofouling has not been a problem to date; therefore, no disinfection of the supply is required. No changes to the existing electron donor addition subsystem are anticipated.

4.2.2 Predesign Operations Approach

Results of the Field Evaluation indicate that the controlling parameter for successful ARD of chloroethenes in the TAN OU 1-07B treatment cell is a sufficient supply of electron donor to drive the system to strongly reducing conditions. Part of the scope of PDP-II is to determine an optimum lactate injection strategy (quantity and frequency). The best lactate injection schedule identified in PDP-II will be continued during Predesign Operations, unless laboratory studies or PDP-II results, suggest that alternate electron donors or injection locations are merited, in which case PDP-III will be implemented. During the ISB Field Evaluation, a total of 300 gal per week of 60% sodium lactate, diluted to 3% (weight/weight) were injected (FDR, p. 2-17; FEWP Appendix G). This schedule will be revised to 24 drums of 60% (weight/weight) solution, diluted to 3% during injection, every two months

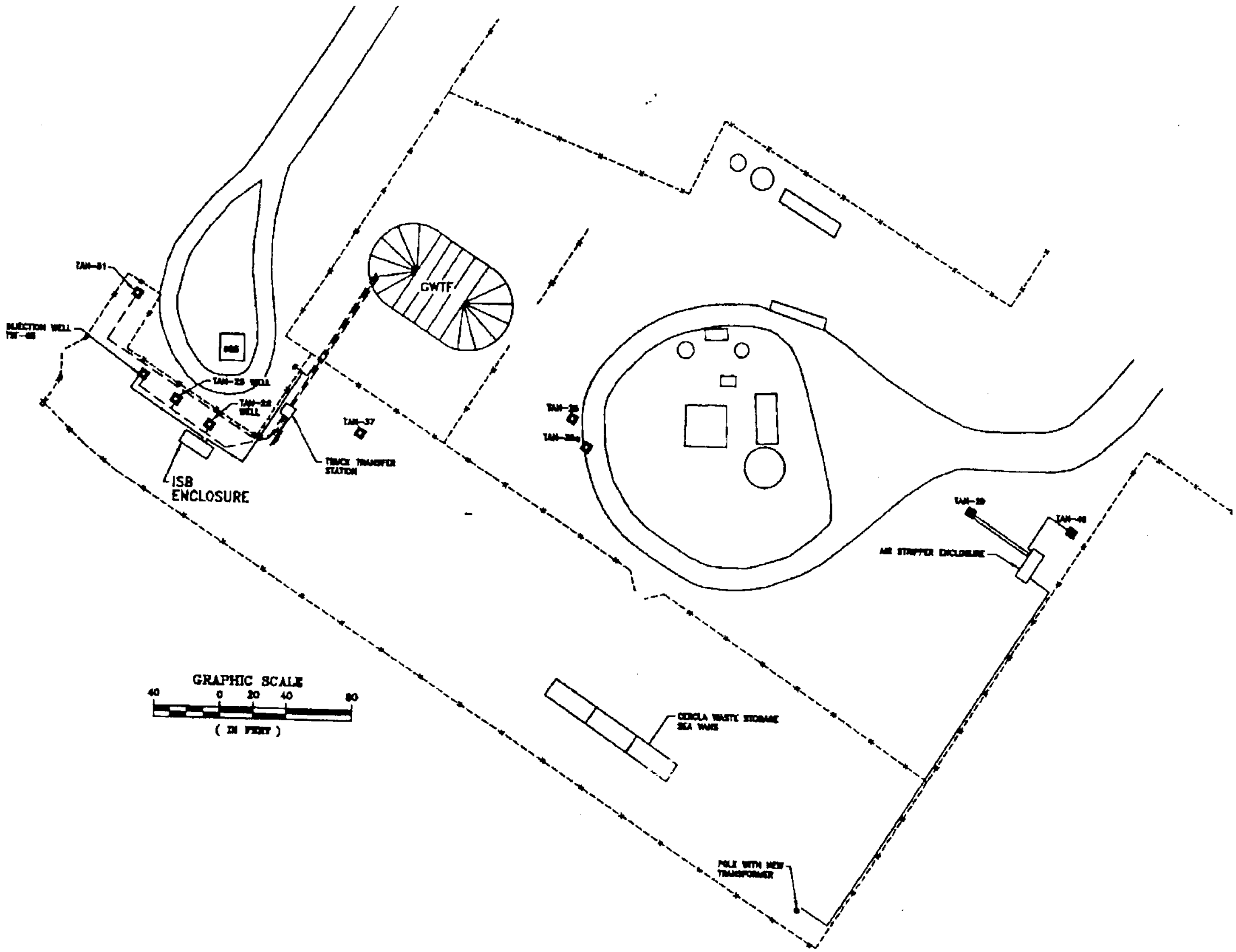


Figure 4-1. ISB Field Evaluation Site layout.

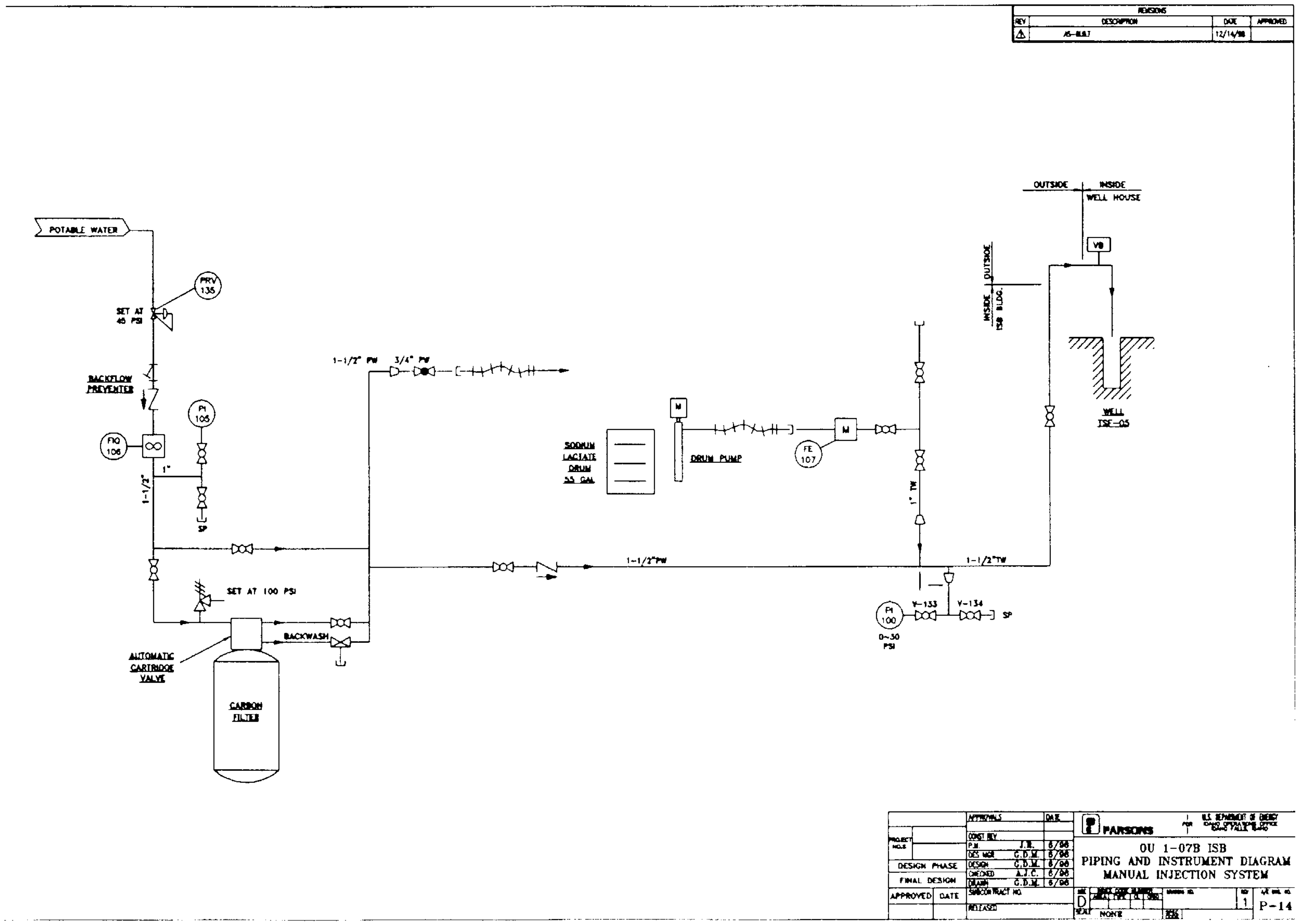


Figure 4-2. ISB electron donor addition system schematic flow diagram.

(160 gal/week) through the Predesign Operations period, based on preliminary results from PDP-II. An updated version of the RT3D numerical model discussed in Section 3.1.2 will be available for use during the Predesign Operations period for simulating ISB. Modeling results may suggest alternative electron donor injection strategies that may be implemented during this period. Any modifications will be discussed with the regulatory agencies and concurrence obtained before proceeding.

4.2.3 Procedures

Technical procedures (TPRs) written for the Field Evaluation to cover both general and specific areas of OU 1-07B operations are listed below in Table 4-1. TPR-163, "Nutrient Injection System Operating Procedure," specifically addresses this subsystem. These TPRs are available in the OU 1-07B administrative record. These TPRs will continue to be controlling documents for these areas of operations. No revisions are required to implement this work plan; however, they will be updated and replaced if hardware, procedures, or requirements change sufficiently to require revisions.

4.2.4 Decontamination and Dismantlement and Deactivation

Decontamination and dismantlement and deactivation (D&D&D) of the ISB nutrient injection system will be addressed in a future D&D&D plan to be prepared in conjunction with the ISB RD/RA WP.

4.3 ASTU Subsystem

4.3.1 Subsystem Components

The ASTU subsystem components include:

- A skid-mounted system enclosure
- An air stripper, including a blower
- A discharge pump
- A groundwater pump
- Control valves with a programmable logic controller.

A schematic flow diagram for this subsystem is provided in Figure 4-3 (FEWP Figure 3-8).

4.3.2 Predesign Operations Approach

The ASTU was operated during the ISB Field Evaluation to capture contaminants leaving the hotspot, by pumping groundwater from well TAN-29. VOCs were air stripped from the extracted water, and the treated water was reinjected into well TAN-41. Collectively this system was called the ASTU. ASTU operations are planned to end no later than 4/30/01, when the duration of reinjection allowed under the Idaho Department of Water Resources letter (IDWR 2000) end; and the New Pump and Treat Facility (NPTF) will have been demonstrated to capture contaminants leaving the hotspot. After either or both of these conditions are met, the ASTU will be maintained in standby mode until at least the beginning of ISB long-term operations.

Table 4–1. TPRs applicable to OU 1-07B operations.

Subsystem/TPR Number	Title
General Operations	
TPR-167	OU 1-07B Operating Procedures Training Requirements
TPR-169	OU 1-07B Facility Operating Minimum Weekly and Daily Inspections/Observations
TPR-6376	OU 1-07B Facility Operation Emergency Light and GWTF Tank Leak Detection System Inspection
TPR-6377	OU 1-07B Facility Operation Decontamination Trailer Inventory and Inspection
TPR-6384	OU 1-07B Facility Operation Leaks/High Water Alarm
Electron Donor Addition	
TPR-163	Nutrient Injection System Operating Procedure
ASTU	
TPR-162	ISB Air Stripper Operation
Monitoring	
TPR-165	ISB Field Sampling Procedure
TPR-166	ISB Field Analyses Procedures

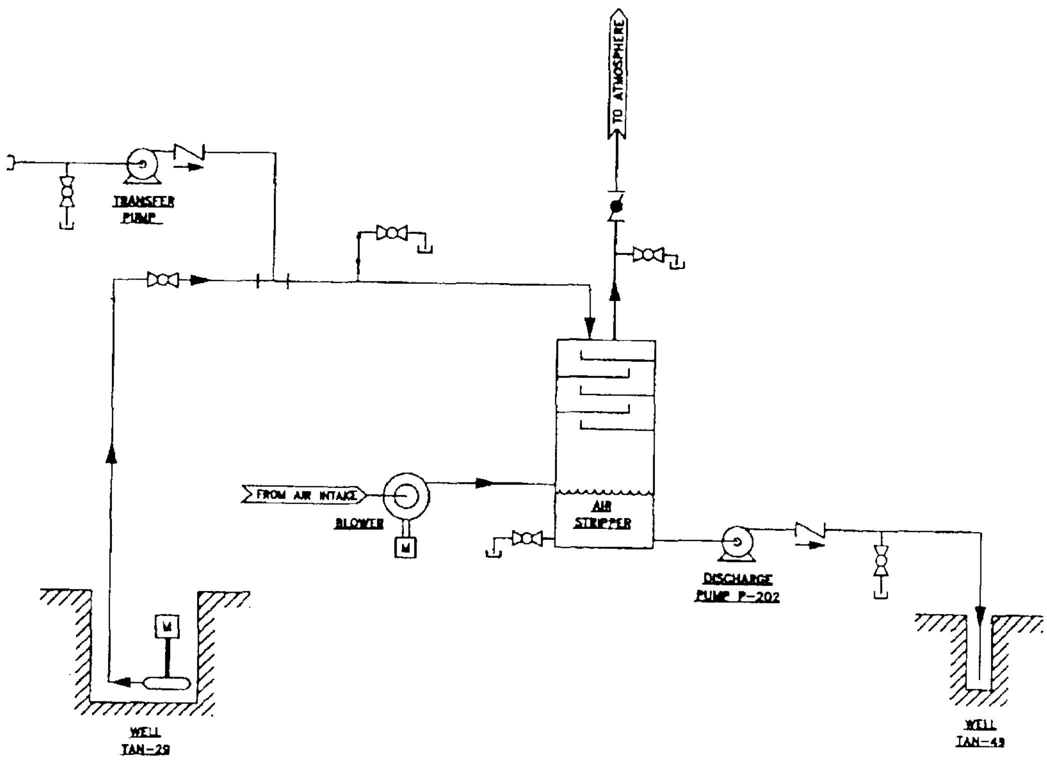


Figure 4-3. ASTU system schematic flow diagram.

4.3.3 Procedures

The ASTU will be maintained in standby mode until at least the beginning of ISB long-term operations. TPRs written for the Field Evaluation to cover both general and specific areas of OU 1-07B operations are listed in Table 4-1. TPR-162, "ISB Air Stripper Operation," specifically addresses this system. These TPRs will continue to be controlling documents for standby maintenance and for renewed operations, if required. TPRs will be revised if hardware, procedures, or requirements change sufficiently to require revisions.

4.3.4 Decontamination and Dismantlement and Deactivation

D&D&D of the ASTU system is currently scheduled for FY 2003. The D&D&D plan is scheduled to be prepared in conjunction with the ISB RD/RA WP.

4.4 Monitoring Subsystem

4.4.1 System Components

The monitoring system components include:

- Trailers
- Generators
- Pump control boxes
- Purge water tanks
- Submersible pumps
- Discharge piping
- Pump wiring
- Groundwater monitoring wells
- Sampling equipment described in DOE (1998b)
- Analytical equipment described in DOE (1998b).

4.4.2 Predesign Operations Approach

The monitoring approach is summarized in Section 5 of this report and described in detail in the SAP.

4.4.3 Procedures

TPRs written for the Field Evaluation to cover both general and specific areas of OU 1-07B operations are listed in Table 4-1. TPR-165, "ISB Field Sampling Procedure" and TPR-166, "ISB Field Analyses Procedure" specifically address this subsystem. These TPRs are available in the OU 1-07B administrative record. These TPRs will continue to be controlling documents for these areas of operations. No revisions are required to implement this work plan; however, they will be updated and replaced if hardware, procedures, or requirements change sufficiently to require revisions.

4.4.4 Decontamination and Dismantlement and Deactivation

No D&D&D of any Monitoring Subsystem components is required.

4.5 Ground Water Treatment Facility D&D&D

The GWTF will be decontaminated and dismantled and deactivated during the Predesign Operations Period. A GWTF D&D&D plan will be prepared and submitted to the EPA and Idaho Department of Environmental Quality for review.

4.6 Interface with ISB RD/RA WP

The FDR (DOE 2000) Section 5.6.1 states that "The results of all predesign and design optimization activities will be compiled and included as an appendix to the Phase C ISB design (i.e., the 90% design or remedial design)." This information will instead be compiled and included in the ISB RD/RA WP, which replaces the Phase C design. This Predesign Operation Work Plan will remain as the controlling document for ISB operations until the ISB RD/RA WP becomes effective in spring 2002. At that time, the ISB RD/RA WP will become the controlling document for ISB remediation.

5. SAMPLING AND ANALYSIS

The objectives cited in Section 2 of this work plan were used as inputs to the EPA's Data Quality Objective process (EPA 1994) to produce a SAP (INEEL 2000c) for ISB Predesign Operations sampling activities. Sampling objectives, frequencies, and locations and analytes, analytical methods, and data management are summarized below and are discussed in detail in the SAP. Deviations from the previous SAP (INEEL 2000d) are also discussed. A conservative tracer test to be performed in FY 2002 is described separately in Appendix A.

5.1 Sampling Objectives

Specific objectives for ISB Predesign Operations activities are discussed in Section 2 of this work plan. Table 5-1 relates these objectives to the location in the SAP where analytes, sampling locations, and sampling frequencies required to support the objectives are identified. The SAP groups the monitoring objectives into two general components, performance monitoring and secondary source mobilization monitoring, as shown in Table 5-1.

5.2 Analytes and Sampling Frequency

Analytes to be measured monthly for ISB Predesign Operations performance monitoring, to support objectives A, B, C, and E, include:

- Chloroethenes
- Ethene/ethane/methane
- Electron donor (lactate)/acetate/propionate/butyrate
- Iron
- Sulfate
- Alkalinity
- Chemical oxygen demand (COD)
- Tritium
- Sr-90
- Temperature, pH, oxidation reduction potential, conductivity, dissolved oxygen (Hydrolab parameters).

Table 5–1. ISB Predesign Operations monitoring parameters.

Monitoring components	Objectives (from Section 2)	Analytes, Location, and Frequency
Performance monitoring	A, B, C, E	Described in SAP (INEEL 2000c) Tables 2-2, 3-1
Secondary source mobilization monitoring	D	Described in SAP (INEEL 2000c) Tables 2-3, 3-2
Laboratory Studies	F	Described in FEWP (DOE 1998a) Appendix F[1]

1. No field activities or groundwater monitoring are associated with the laboratory studies.

The following analytes will be discontinued:

- Carbon dioxide—This parameter will be discontinued because alkalinity is an effective surrogate and provides more precise data.
- Chloride—This parameter will be discontinued because chloroethenes are more indicative of the extent of dechlorination. Additionally, high background chloride concentrations prevent meaningful interpretations of these data.
- Nitrate—This parameter will be discontinued because sulfate is a better indicator of redox conditions, and because no nutrient limitations are evident.

Analytes and sampling frequencies for assessing secondary source mobility, to support Objective D, are:

- Gamma emitters (Cs-137) (quarterly)
- Total metals (quarterly)
- Alpha emitters (annually)
- Tritium (monthly).

Tritium has proven to be a good indicator of source mobility and will continue to be sampled monthly. Cesium-137 sampling frequency will be reduced to quarterly. Alpha sampling frequency will be reduced to annually because little source mobilization of metals and radionuclides has been evident. Total metals sampling frequency will be reduced to quarterly. SVOCs will be discontinued since no mobilization of SVOCs has been observed. Sampling frequencies for nutrients including phosphate and ammonia nitrogen will be reduced to twice per year because no nutrient limitations are evident.

5.3 Sampling Locations

All 13 monitoring locations sampled under PDP-IIb will be continued. Specific locations to be sampled are identified in the ISB PDO SAP (INEEL 2000c).

5.4 Sampling Procedures

ISB field sampling procedures and field analysis procedures are addressed in Idaho National Engineering and Environmental Laboratory (INEEL) TPRs prepared for the Field Evaluation and are referenced in the ISB Predesign Operations SAP (INEEL 2000c). TPRs specific to sampling and analysis are listed in Table 4-1 and include TPR-165, "ISB Field Sampling Procedure," and TPR-166, "ISB Field Analyses Procedure." No revisions are required.

5.5 Quality Assurance

Off-site VOC splits will be reduced in frequency to quarterly because good agreement has been observed between results from on-Site solid phase microextraction and off-Site EPA SW 846 Method 8260B analyses, as reported in INEEL (2000a), Section 3.1.3. Through July 1999, 92% of VOC splits showed relative percent differences of less than or equal to the acceptable level of 25% specified in DOE (1998). This does not include results where deterministic errors were identified, as discussed in INEEL

(2000a). Other QA procedures are described or referenced in the ISB Predesign Operations SAP (INEEL 2000c).

5.6 Data Management

The data management procedures defined for the FEWP will be continued for the Predesign Operations period. The *Data Management Plan for the INEL Environmental Restoration Program* (INEEL 1995) was used to define the approach used in the FEWP. The ISB Predesign data manager (see Table 8-2 for responsible staff) is responsible for compiling data from all sampling and analyses, entering them into an electronic format, and generating summary plots. Compiling results for analyses not performed on-Site will be coordinated with the Sample Management Office. Compiling results for on-Site analyses will be coordinated with the ISB sampling and analysis field team leader (see Table 8-2 for responsible staff).

6. DATA ANALYSIS AND INTERPRETATION

Data analysis and interpretation for PDP-II, as described in the FEWP Appendix E, will continue during the Predesign Operations period with the reduced list of analytes and decreased sampling frequencies described in Section 5.2 of this report. Data analysis and interpretation, as described for PDP-III in the FEWP Appendix E, will apply if this phase is implemented. Data analysis and interpretation for the conservative tracer test to be performed in FY 2002 are described separately in Appendix A.

7. ENVIRONMENT, SAFETY, AND HEALTH; QUALITY; AND WASTE MANAGEMENT

7.1 Environment, Safety and Health

The OU 1-07B Health and Safety Plan (HASP) (INEEL 1998a) establishes procedures and requirements that will be used for all activities associated with OU 1-07B, including Predesign Operations. The major field activities for the ISB Predesign Operations period are system operations and groundwater sampling, as described in Section 4. The OU 1-07B HASP includes a hazard assessment for all anticipated activities and specifies procedures and equipment to be used for worker safety. This HASP will be revised if conditions change sufficiently to require it.

7.2 Quality Assurance

The quality level for all activities during the ISB Predesign Operations period is Quality Level 3 in accordance with Section 13 of INEEL (2000b) and MCP-540, "Graded Approach & Quality Level Assignment." Data to be collected will include field analyses, INEEL Operational Review Board analyses, and off-Site laboratory confirmation of INEEL analyses.

Field analyses will be performed in accordance with the manufacturer's specifications, and duplicates will be analyzed to ensure that the precision meets project requirements as shown in the SAP. INEEL Operational Review Board analyses and reporting will be performed as described in the SAP. Sampling and analysis tables are provided in the SAP.

7.3 Waste Management

All waste managed during the ISB Predesign Operations Period will be managed in accordance with the provisions of the *Waste Management Plan for Test Area North Final Groundwater Remediation Operable Unit 1-07B* (INEEL 1998b). Equipment and material decontamination requirements and procedures are specified in the *Interim Decontamination Plan for Operable Unit 1-07B* (INEEL 1998c). All of the materials used in the electron donor addition system are nonhazardous. Any wastes generated from operating the electron donor addition system will be managed as nonhazardous solid waste. This plan will be revised if conditions change sufficiently to require it.

8. BUDGET, RESPONSIBILITIES, AND SCHEDULE

8.1 Cost Estimate

The cost estimate for Predesign Operations is summarized in Table 8-1. Costs accrued to Predesign Operations begin on May 1, 2001, and continue through June 2002.

Table 8–1. Cost estimate summary for ISB Predesign Operations.[1] Costs are FY 2000 dollars.

Cost element	Labor	Materials	Subcontracts	Total
ASTU/GWTF Standby Ops	$17,264.00	$6,661.20	$0.00	$23,925.20
ISB Operations	$9,975.00	$145,236.00	$0.00	$155,211.00
ISB Groundwater monitoring	$362,232.00	$54,425.00	$83,810.00	$500,467.00
RT3D numerical model	$6,000.00	$2,500.00	$31,500.00	$40,000.00
Laboratory studies	$83,840.00	$5,633.00	$0.00	$89,473.00
Technical Integration	$115,800.00	$1,395.00	$7,320.00	$124,515.00
Total	$595,111.00	$215,850.20	$122,630.00	$933,591.20

[1] Operating period is 5/1/01 through 6/1/02.

8.2 Organization and Responsibility

Table 8-2 shows task descriptions and responsible personnel for Predesign Operations activities.

Table 8-2. OU 1-07B Predesign Operations Roles and Responsibilities.

Functional Role	Responsible Organization	Person
Operable Unit 1-07B project manager	INEEL	J.S. Rothermel
ISB technical lead	INEEL	K.S. Sorenson
Sampling and analysis field team leader	INEEL	D. Shanklin
Data Manager	INEEL	J.F. Keck
ISB Predesign project engineer	INEEL	L.O. Nelson
Engineering and operations		
– Operations Strategy	INEEL	K.S. Sorenson
– Design	INEEL	A.J. Cram
– Field Operations Supervisor	INEEL	M.E. Bartholomei
– Groundwater monitoring field coordinator	INEEL	R. Carroll

8.3 Schedule

A schedule for OU 1-07B ISB Predesign Operations is provided on the following pages. The overall OU 1-07B project schedule will be provided in the revised Remedial Design Scope of Work.

Figure 8–1. Schedule for ISB Predesign Operations.

9. REPORTS

The FDR (DOE 2000) Section 5.6.1 states that "The results of all predesign and design optimization activities will be compiled and included as an appendix to the Phase C ISB design (i.e., the 90% design or remedial design)." This information will instead be compiled and included in the ISB RD/RA WP, which replaces the Phase C design. These data will be used as a design basis to define operating parameters and other 90% design tasks. No interim reports are planned prior to submittal of the ISB RD/RA WP.

10. REFERENCES

Clements, T.P., 1988, RT3D; *A Modular Computer Code for Simulating Reactive Multi-Species Transport in 3-Dimensional Groundwater Aquifers*, Version 1.0, PNNL-SA-11720, Pacific Northwest National Laboratory, Richland, WA

DOE 19982, *Enhanced In Situ Bioremediation Work Plan, Test Area North, Operable Unit 1-07B*, DOE-ID-10639, Revision 0.

DOE 1998a, *Enhanced In Situ Bioremediation Field Evaluation Work Plan, Test Area North, Operable Unit 1-07B*, DOE/ID-10639, September 1998.

DOE 2000, *Field Demonstration Report, Test Area North Final Groundwater Remediation, Operable Unit 1-07B*, DOE/ID-10718, March 2000.

EPA 1994, *Guidance for the Data Quality Objectives Process*, EPA/600/R-96/055, September 1994.

IDWR 2000, Letter from Scott Anderson to Ms. Kathleen Hain Re: "Extension for Temporary Use of Remediation Wells for Injection of ISB Treatability Study Amendments and Temporary Use of Injection Well TAN-49 for Injecting Treated Water During Phase B Remediation," January 20, 2000.

INEEL 1995, *The Data Management Plan for the INEL Environmental Restoration Program*, INEL-95/0257, Revision 1.

INEEL 1998a, *Health and Safety Plan for Test Area North Final Groundwater Remedial Action Operable Unit 1-07B*, Lockheed Martin Idaho Technologies Co., INEEL/EXT-98-00403, Revision 0.

INEEL 1998b, *Waste Management Plan for Test Area North Final Groundwater Remediation Operable Unit 1-07B*, Lockheed Martin Idaho Technologies Company, INEEL/EXT-98-00267, Revision 0.

INEEL 1998c, *Interim Decontamination Plan for Operable Unit 1-07B*, Lockheed Martin Idaho Technologies Company, INEEL/Ext-97-01287, Revision 0.

INEEL 2000a, *Field Evaluation Report of Enhanced In Situ Bioremediation, Test Area North, Operable Unit 1-07B (Draft)*, INEEL/EXT-2000-00258, Revision A.

INEEL 2000b, *Implementing Project Management Plan for the INEEL Remediation Program*, Revision 6, INEEL/EXT-97/00032.

INEEL 2000c, Sampling and Analysis Plan for Enhanced In Situ Bioremediation Predesign Operations, Test Area North, Operable Unit 1-07B, INEEL/EXT-2000-00925, Revision 0, March 2001.

INEEL 2000d, *Sampling and Analysis Plan for the Enhanced In Situ Bioremediation Field Evaluation Test Area North, Operable Unit 1-07B*, INEEL/EXT-98-00421, October 2000, Revision 2.

Appendix A

2002 Tracer Test Work Plan

CONTENTS

FIGURES

TABLES

ACRONYMS

ARD	anaerobic reductive dechlorination
COC	chain of custody
COD	chemical oxygen demand
DQO	data quality objective
EPA	Environmental Protection Agency
FEWP	Field Evaluation Work Plan
FTL	field team leader
FY	fiscal year
HASP	Health and Safety Plan
INEEL	Idaho National Engineering and Environmental Laboratory
IRC	INEEL Research Center
ISB	in situ bioremediation
ISE	ion-specific electrode
NPTF	New Pump and Treat Facility
ORP	oxidation reduction potential
OU	operable unit
POD	plan of the day
QA	quality assurance
QAPjP	Quality Assurance Project Plan
ROD	Record of Decision
SAP	Sampling and Analysis Plan
TAN	Test Area North
TPR	technical procedure

In Situ Bioremediation 2002 Tracer Test Work Plan Test Area North Operable Unit 1-07B

A-1. INTRODUCTION

This work plan describes the 2002 Tracer Test to be performed at Idaho National Engineering and Environmental Laboratory (INEEL) Test Area North (TAN) Operable Unit (OU) 1-07B. This tracer test will support implementation of the final remedy for OU 1-07B, which is defined in the Record of Decision (ROD) Amendment (DOE-ID 2001) for the hotspot as in situ bioremediation (ISB) – anaerobic reductive dechlorination (ARD).

The 2002 Tracer Test will be divided into five phases:

1. Sodium bromide injection – Potable water amended with sodium bromide, a conservative tracer, will be injected into TSF-05.

2. Sodium lactate and sodium iodide injection – Potable water, sodium lactate, and sodium iodide, a conservative tracer, will be injected into TSF-05.

3. Groundwater sampling – Groundwater will be sampled from various wells surrounding TSF-05 that are identified in Section A-3.

4. Sample analysis – Groundwater will be analyzed for bromide, iodide, chemical oxygen demand (COD), and lactate and fermentation product concentrations.

5. Data analysis and reporting – Data will be analyzed using methods described in Section A.3.5; results will be reported in an appendix of the FY 2002 Annual Report.

The overall goals of the test are to determine porosity in the vicinity of TSF-05, relative to results obtained in 1998 and reported in the *Site Conceptual Model: 1998 and 1999 Activities, Data Analysis, and Interpretation for Test Area North, Operable Unit 1-07B* (Wymore et al. 2000); and to determine electron donor fate and transport parameters required for groundwater modeling. Activities required to implement the test will be performed under existing work controls and procedures. Results of the test will be used to update the ISB conceptual model and to refine the numerical model used to predict electron donor distribution resulting from various injection strategies. Refer to Figure A-1-1 for an overview of the well locations.

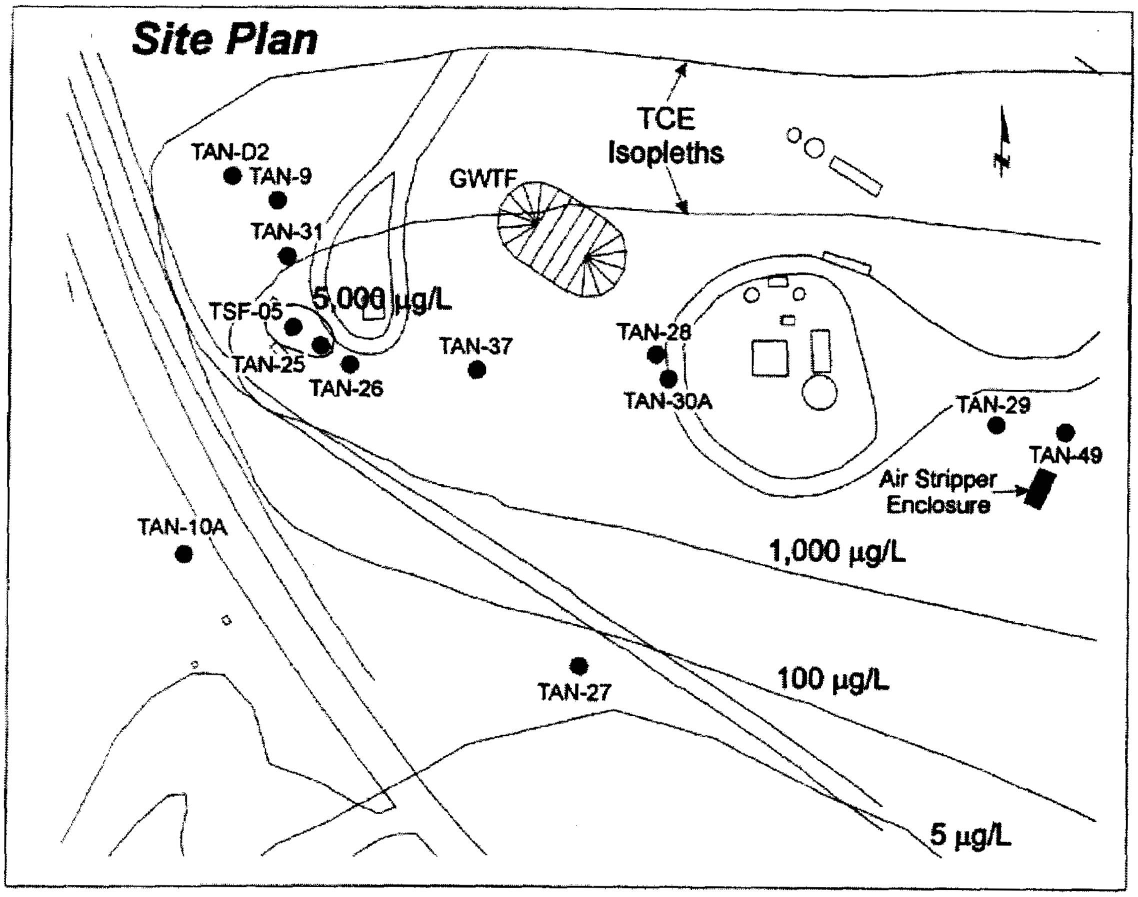


Figure A-1-1. Site map and monitoring locations.

A-2. OBJECTIVES

The two overall goals of the 2002 Tracer Test are: 1) to assess changes in the residual source distribution resulting from several years of ISB operations, and 2) to provide additional data necessary to improve numerical modeling of electron donor injection strategies. These objectives are discussed in the context of the data quality objectives (DQOs) process as defined by *Data Quality Objectives Process for Superfund, Interim Final Guidance* (EPA 1994). This process was developed by the Environmental Protection Agency (EPA) to ensure that the type, quantity, and quality of data used in decision-making are appropriate for the intended application. The process includes several steps, each of which has specific outputs that together form the DQOs for a given project. Each of the following subsections corresponds to a step in the DQO process and the output for each step is provided as appropriate.

A-2.1 Problem Statement

The first step in the DQO process is simply to state the problem to be addressed and to put it in its programmatic context. The appropriate problem statements as they apply to the 2002 Tracer Test are given below. Another output of this step, common to all of the activities, is an estimate of the budget, schedule, and personnel. The budget for the 2002 tracer tests is addressed in Section A-5. The personnel responsible for the 2002 tracer tests sampling activities are presented in Table A-2-1 and the schedule is presented in Section A-6.

Table A-2-1. 2002 Tracer Test Roles and Responsibilities.

Functional Role	Responsibilities	Person
OU 1-07B ISB Technical Lead	Overall ISB technical direction	Kent Sorenson
Task Supervisor	Supervise tracer test	John Keck
Task Manager	Implement tracer test	Kevin Harris
Field Team Leader (FTL)	Implement field sampling, coordinate activities	Riena Carroll
Field Lab Lead (FLL)	Direct field lab operations	Patrick Lebow
Field Lab Technicians (2)	Assist the field lab lead as directed	Carol Strong, TBD
Field engineers	Treat purge water, develop and implement work controls and safety	Kory Edelmayer/ Marty Barthomomei
Samplers (4)	Sample groundwater	TBD

The 2002 Tracer Test is being performed to address five data gaps. The first is to estimate porosity in the vicinity of Well TSF-05, relative to results from the 1998 tracer test (Wymore et al. 2000). The bromide tracer measurements will assess changes in porosity, and thereby changes in the residual source distribution in the vicinity, after three and a half years of ISB. The second data gap is the Freundlich distribution coefficient, measured as Kd for the electron donor, sodium lactate, which has been periodically injected into TSF-05 to facilitate ARD since 1999. The third data gap is to estimate the electron donor degradation rate measured as a first-order degradation rate (k) for COD. The sodium iodide tracer injected with the sodium lactate will determine estimates of both sorption and decay rates. The fourth data gap is the porosity near the edge of and outside the residual source area. The iodide tracer measurements in Wells TAN-D2 and TAN-37 will be used for this purpose. The fifth data gap is the correlation between actual lactate fermentation and electron donor utilization rates and COD utilization rates. Filling all five data gaps will greatly improve numerical modeling of electron donor distribution that will be used to evaluate electron donor injection strategies for the ISB system.

A-2.2 Decision Identification

This step in the DQO process is used to identify the decisions and the potential actions that will be affected by the data collected.

The overall objectives of the 2002 Tracer Test are to (1) determine condition of the sludge remaining in the residual source area surrounding TSF-05, determined quantitatively by estimating porosity in the area; and (2) determine fate and transport parameters for the electron donor, including effective porosity (as for (1) above), electron donor sorption, and electron donor degradation. Results of this tracer test will be used to determine the effects of ISB on effective porosity near TSF-05, compared to 1998 results (Wymore et al. 2000); and to estimate sorption and decay rates for the electron donor. The actions that may be taken based on this data are to refine the numerical model parameterization and calibration, and to modify the operating strategy.

A-2.3 Decision Inputs

Decision inputs are the parameters required to help make the decisions identified in the previous section. These inputs are summarized in Table A-2-2.

Table A-2-2. Decision inputs for the 2002 tracer test.

Parameter	Data Gap/Significance	Potential Analytical Method	Precision /Accuracy[a]
Bromide	1/Conservative tracer; required to determine travel times	Ion-specific electrode (ISE)	±10% / ±10%
Iodide	2, 3, 4/Conservative tracer; required to determine travel times	Ion-specific electrode (ISE)	±10% / ±10%
Chemical Oxygen Demand	2, 3/Measure of the total electron donor present; required to determine Kd and degradation rate	Hach Field Test Kit	±10% / ±50%
Lactate	5/Electron donor	Ion Chromatography	±10% / ±25%
Acetate/Propionate/Butyrate	5/Measure of anaerobic activity, required to correlate the electron donor to COD	Gas chromatography/flame ionization detection (GC/FID)	±10% / ±50%

a. See Section A-2.6.

Decision inputs will be derived from two separate phases for the 2002 tracer test. Phase 1 will determine porosity in the residual source area, using sodium bromide as the tracer and water as the injection fluid. A similar approach was used successfully in 1998. Comparison of the results between the two tests will be used to assess changes in porosity due to ISB activities, potentially associated with changes in the distribution of sludge remaining in the residual source area.

Phase 2 will determine sorption and decay in the residual source area and surrounding areas, using sodium iodide as the tracer and sodium lactate and potable water as the injection fluid. Injection of a tracer with lactate will allow for determining sorption by calculating relative velocities of the tracer and electron donor. Decay can then be determined by solving transport equations using the porosity determined in Phase 1, and the sorption determined in Phase 2, and iteratively solving the governing fate and transport equations using a numerical model. While both sorption and decay may affect travel time, the observation wells used to determine sorption, TAN-25 and TAN-31, are sufficiently close to TSF-05 and electron donor arrival times sufficiently short that decay should be dominated by sorption, and the differences in peak arrival times can be initially assumed to be due to sorption alone.

The necessity for performing the tracer test in two phases is that the lactate injection solution likely behaves differently than water alone. Based on the discussion of fluid flow in porous media provided below, performing the tracer tests in two phases is a simple way to reliably determine porosity, assess changes in sludge distribution, and estimate sorption and decay rates.

Fluid Flow in Porous Media

Fluid flow in porous media is governed by Darcy's Law, as shown in Equation 1:

$$v = \frac{Ki}{\eta} \quad (1)$$

where:

v = groundwater velocity (L/t)

K = hydraulic conductivity (L/t)

i = hydraulic gradient (L/L, dimensionless)

η = effective porosity (dimensionless).

Hydraulic conductivity is a function of both the fluid and the medium as shown in Equation 2:

$$K = \frac{k\rho g}{\mu} \quad (2)$$

where:

K = hydraulic conductivity (L/t)

k = intrinsic permeability, a property of the media (L^2)

ρ = fluid density (M/L^3)

μ = fluid viscosity (M/Lt)

g = gravitational constant (L/t^2).

The density and viscosity of the lactate solutions are different than for water alone and therefore hydraulic conductivities will be different, until the injection concentration is reduced by dilution to a level where effects are insignificant. Different hydraulic conductivities result in different velocities for the two fluids. These differences would make porosity estimates less reliable if only a single tracer were injected with the lactate solution. Essentially repeating the bromide-water test used in 1998 will allow for more confidence in the porosity estimates, and thereby reduce uncertainty in the sorption and decay estimates, as well as facilitating a reliable assessment of the impact of bioremediation activities on the sludge distribution.

Density differences also affect vertical fluid migration. The lactate injection solution has been observed to migrate vertically downward as a function of injection solution concentration. Initial injections of pure 60% sodium lactate (having a specific gravity of 1.32, or 32% more dense than water at 20°C) were observed to rapidly sink, as evidenced by preferential distribution to deeper Wells TAN-26, TAN-30A and TAN-37C. Current injection concentrations of about 3% by volume have been observed to deliver higher COD concentrations to shallower locations while concentrations of 6% by volume have been observed to migrate deeper.

Relatively small density differences affect fluid flow. EPA (1993) states that "...density difference of about 1% influence fluid flow in the subsurface. Density differences as small as about 0.1% have been demonstrated to cause contaminated water to sink in physical model aquifers over several weeks." The density of a roughly 6% by volume solution of sodium lactate is estimated at 1.019, which is about 2% more than the density of water. This is well above the threshold for density influence on flow in porous media based on the EPA citation. Reducing the injection concentration to 3% by volume would reduce the density difference to about 1%, still at or above the level cited by EPA as resulting in density-driven flow.

A-2.4 Study Boundaries

This step in the DQO process defines the boundaries of the study to clarify the sample domain. The boundaries include spatial boundaries and temporal boundaries. The spatial boundaries simply define the physical extent of the study area, and may be subdivided into specific areas of interest. The temporal boundaries define the duration of the study, or specific parts of the study.

The spatial boundaries for the operation tracer test are defined by the wells to be sampled. These sampling locations are based on data from the 1998 tracer test and wells where electron donor from the March 2002 injection have been detected. The temporal boundaries of this tracer test are defined by the duration of the test as defined by the sampling schedule in Section A-6 to the completion of the sample analyses.

A-2.5 Decision Rule

The objective of this step is to develop a logical statement that defines the conditions that would cause the decision maker to choose among alternative actions. If results from the tracer test show that the effective porosity is different than previously observed, and/or sorption and degradation rates differ from those currently used in the model, then the model will be reparameterized and recalibrated and new injection simulations will be performed.

A-2.6 Decision Error Limits

Decision error limits establish appropriate performance goals for data uncertainty. However, the decisions to be made at the end of these activities are not amenable to quantitative decision errors, unlike decisions regarding the number of samples to collect when looking for contamination. Nevertheless, defining the allowable uncertainty in decision inputs is useful. These values are provided in Table A-2-2. For these analytes, the uncertainty allowable was based on a consideration of the importance of each individual data point for that analyte.

A-2.7 Design Optimization

The purpose of design optimization in the DQO process is to identify the best sampling and analysis design that satisfies all of the previous steps in the process. This includes identifying the data that need to be collected (analytes), their purpose, the appropriate analytical methods, and sampling locations and frequencies. The analyses, their purpose, and the analytical methods listed in Table A-2-2 will be used for these sampling activities. The sampling locations and frequencies are based on results from the 1998 tracer test, the results from sampling for electron donor over the past 3 years, and predictions from the ISB numerical model (Arnett 2002) see Figure A-2-1. These locations and frequencies are presented in Section A-3.

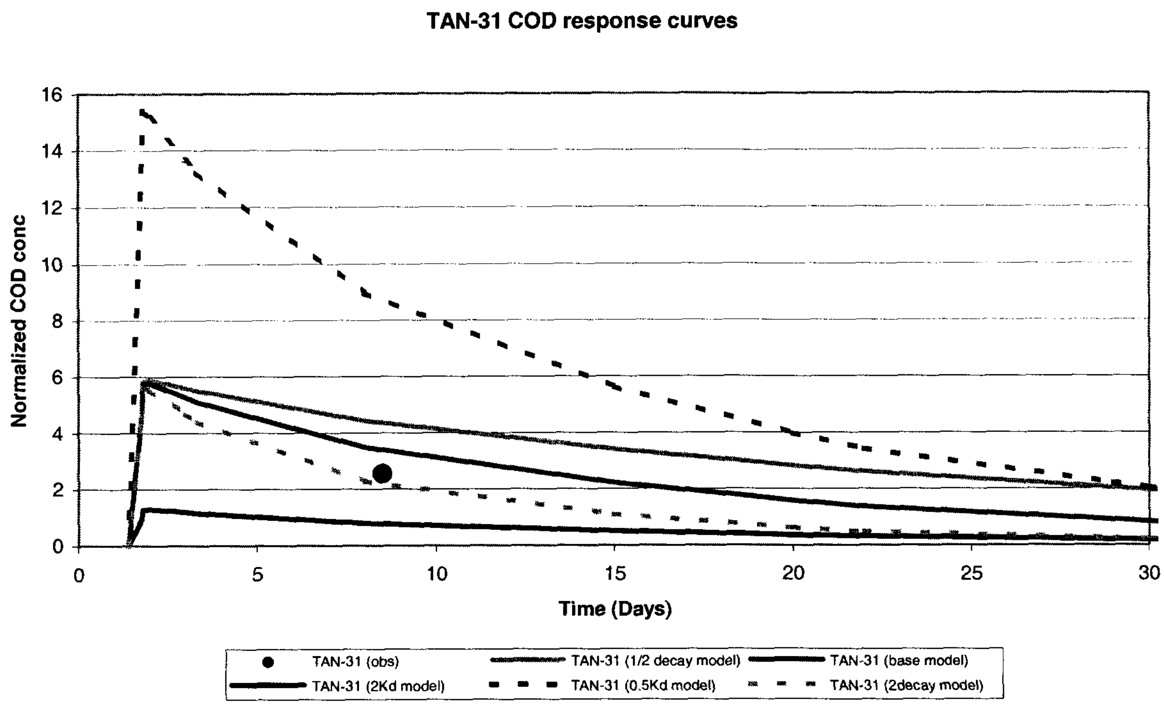


Figure A-2-1. Model generated TAN-31 COD response curves.

Figure A-2-1 illustrates how the model predicts COD concentrations at TAN-31 as a function of time after electron donor injection. The differences in how sorption and decay affect the simulated COD response curves illustrate how both parameters can be determined by measuring the actual COD breakthrough curve. It is clear that the magnitude of the COD peak is entirely dependent on Kd. When decay was varied by a factor of 4, no significant change in the peak was observed, while the same variation of Kd produces more than a factor of 7 change in the COD peak value. Once Kd is determined based on the measured COD peak, decay can be adjusted in the simulation to match the tail of the COD response curve. Another important point illustrated in Figure A-2-1 is that the sampling frequency required to resolve the response curve adequately changes with time. A high frequency of sample collection is required to measure the early portion of the response curve, including the peak, because changes in COD are very rapid. A much lower sample frequency is required beyond the peak because COD changes are significantly slower. This strategy is reflected in Section A-3.

A-3. METHODS

The five phases of the 2002 Tracer Test are discussed in this section. Procedures for each phase are summarized in Table A-3-1. All participants will be involved in a walkdown of the injection/sampling site prior to the start of the tracer test, at which time a prejob brief will be given. In addition, a plan of the day (POD) meeting will be held at the beginning of each day per TPR-165, "Low Flow Groundwater Sampling Procedure." A detailed schedule of the 2002 Tracer Test is located in Section A-6.

Table A-3-1. Procedures/references used for tracer test tasks.

Task	Procedures
1. Sodium bromide injection	TPR-163
2. Dilute sodium lactate and sodium iodide injection	TPR-163
3. Groundwater sampling	TPR-165, Section A3.3
4. Sample analysis	Section A-3.4 and manufacturers specifications for bromide and iodide analysis using specific ion electrodes; TPR-166 for COD.
5. Data analysis and reporting	Data analysis methods as described in the Field Evaluation Work Plan (FEWP) and the Field Evaluation Report (FER); results reported in an Appendix of the FY 2002 Annual Report.

A-3.1 Phase 1—Sodium Bromide Injection

The sodium bromide injection will take place on the first day of the 2002 Tracer Test. The sodium bromide tracer solution will be prepared according to calculations and the procedure in Section A-7. Potable water and sodium bromide tracer solution will be injected into TSF-05 during this phase. Rates and durations for the sodium bromide tracer injection are specified in Table A-3-2. A peristaltic pump will be used to inject the tracer solution through the ISB injection system, as specified in TPR-163, "Nutrient Injection System Operating Procedure." Injection of the tracer solution will stop when the entire amount of solution has been injected, however, potable water injection will continue until sampling is complete for this phase. Samples of the tracer solution and potable water mixture, taken from the sample port in the injection line, will start at the same time as the tracer injection, at a frequency specified in Section A-3.3, until the entire amount of tracer solution has been injected.

Table A-3-2. Tracer test injection details.

Tracer	Volume of Tracer Solution	Mass of Tracer	Flow Rate Tracer	Flow Rate Water	Flow Rate Lactate	Concentration of Tracer ion injected into TSF-05	Duration
Sodium Bromide	79 gal	36 kg	11.1 L/min (3 gpm)	75.7 L/min[a] (20 gpm)	N/A	12,000 mg/L	26.3 min
Sodium Iodide	67 gal	72 kg	11.3 L/min (3 gpm)	132.5 L/min[b] (35 gpm)	7.6 L/min (2 gpm)	18,000 mg/L	22.3 min

a. Potable water injection will continue at 75.7 L/min until sampling at TAN-25 and TAN-31 is concluded on Day 1.

b. A routine electron donor injection will follow the iodide tracer injection. A total of 48 drums (2,640 gal) of 60% lactate will be injected at 2 gpm lactate:36 gpm potable water, resulting in about 50,000 gal of 3% lactate.

A-3.2 Phase 2 –Sodium Lactate and Sodium Iodide Injection

The sodium lactate and sodium iodide injection will take place on the second day of the 2002 Tracer Test. The sodium iodide tracer solution will be prepared according to calculations and procedures in Section A-7. Potable water, sodium lactate, and sodium iodide tracer solution will be injected into TSF-05 during this phase. Rates and durations for the sodium iodide tracer injection are specified in Table A-3-2. A peristaltic pump will be used to inject the tracer solution through the ISB injection system as specified in TPR-163. When the entire amount of sodium iodide tracer solution has been injected, the flowrate of the potable water will be increased to 36 gpm, and a routine electron donor injection will follow. A total of 48 drums (2640 gal) of 60% lactate will be injected at 2 gpm resulting in approximately 50,000 gal of 3% lactate being injected. Sampling of the tracer solution and potable water mixture at the injection line, will start at the same time as the tracer injection, at a frequency specified in Section A.3.3, until the entire amount of tracer solution has been injected.

A-3.3 Phase 3 – Groundwater Sampling

Groundwater samples will be collected throughout the 2002 Tracer Test. Field guidance forms outlining sample collection location, sample numbers, and analyses requested will be provided for each sample location by the Sample Management Office (SMO). The forms will be generated from the Integrated Environmental Data Management System database, which will ensure unique sample numbers. Refer to *Sampling and Analysis Plan for Enhanced In Situ Bioremediation Predesign Operations Test Area North, Operable Unit 1-07B* (INEEL 2001b) for an overview of the systematic character sample identification code that will be used to identify all samples.

Sample locations, frequencies, and analytes are outlined in Table A-3-3. Samples will be collected per the ISB sampling procedure described in TPR-165. Refer to Figure A-1-1 for an overview of all groundwater monitoring well locations. Influent samples from Phase 1 and Phase 2 will also be collected at the sample port in the injection line to verify calculations of the bromide and iodide/COD injection concentrations. Sample frequencies are based on the estimated peak arrival time at a given monitoring well. These frequencies are subject to change based on field observations.

The criterion for discontinuing sampling at wells TAN-25 and TAN-31 every four or six minutes during Phase 1 and 2 is when the concentration of tracer declines to less than 10% of the peak value for two consecutive samples, or when sampling must be discontinued due to time constraints. During the 1998 tracer test, breakthrough of the bromide tracer was observed at TAN-25 and TAN-31 at 50 minutes and 120 minutes, respectively. Based on these breakthrough times, it is anticipated that the sampling at wells TAN-25 and TAN-31 every 4 or 6 minutes will be discontinued based on the tracer concentration criterion. The criterion for discontinuing sampling at wells TAN-26 and TAN-D2 is when concentration of COD declines to less than 10% of the peak value for two consecutive samples.

Once iodide tracer is detected at TAN-26 and/or TAN-D2, then TAN-37A, TAN-37B, and TAN-37C will be sampled twice per day. All samples will be analyzed as specified in Section A-3.4.

Table A-3-3. 2002 tracer test sampling.

Location	Sampling Period	Frequency	Analyte
TAN-25	Day 1 – Day 5, Day 8 – Day 11	Every 4 minutes on Day 1 and Day 2[a], Once daily	Bromide, Iodide, COD[b], Lactate/Acetate/Propionate/Butyrate[c]
TAN-26	Day 1 – Day 5, Day 8 – Day 11	Once on Day 1 and Day 2, twice daily thereafter[d]	Bromide[e], Iodide, COD, Lactate/Acetate/Propionate/Butyrate
TAN-31	Day 1 – Day 5, Day 8 – Day 11	Every 6 minutes on Day 1 and Day 2[a], Once daily	Bromide, Iodide, COD[b], Lactate/Acetate/Propionate/Butyrate[c]
TAN-37A	Day 3 – Day 5 Day 8 – Day 11	Once/Twice daily[f]	Iodide, COD
TAN-37B	Day 3 – Day 5 Day 8 – Day 11	Once/Twice daily[f]	Iodide, COD
TAN-37C	Day 3 – Day 5 Day 8 – Day 11	Once/Twice daily[f]	Iodide, COD
TAN-D2	Day 2 – Day 5 Day 8 – Day 11	Once on Day 2, twice daily thereafter[d]	Iodide, COD, Lactate/Acetate/Propionate/Butyrate
Injection Line	Day 1, Day 2	Every 1 minute during tracer injection	Bromide, Iodide[g]

a. Sampling will be discontinued when the concentration of tracer at the well declines to less than 10% of the peak value for two consecutive samples or until 4:00 p.m. on Day 1, or 3:00 p.m. on Day 2. At this time, a sample will be taken at TAN-26 on Day 1, and samples will be taken at TAN-26 and TAN-D2 on Day 2. TAN-25 and TAN-31 will then be sampled once more as time allows on Day 2.

b. COD and iodide will not be analyzed at this location during Day 1 of the 2002 Tracer Test and bromide will not be analyzed at this location after Day 1 of the 2002 Tracer Test.

c. Samples will not be taken for lactate/acetate/propionate/butyrate on Day 1 and when sampling occurs every 4 or 6 minutes on Day 2. Samples will be taken for lactate/acetate/propionate/butyrate after TAN-26 and TAN-D2 are sampled on Day 2 if time allows and for the remainder of the test.

d. Sampling will be discontinued when the concentration of COD at the well declines to less than 10% of the peak value for two consecutive samples.

e. Bromide will not be analyzed after Day 1.

f. Once iodide tracer is detected at TAN-26 and/or TAN-D2, then TAN-37A, TAN-37B, and TAN-37C will be sampled twice daily.

g. Bromide will be analyzed on Day 1and Iodide will be analyzed on Day 2.

A-3.3.1 Sodium Bromide Sampling

TAN-25 and TAN-31 will be purged prior to the tracer injection as specified in Section A-3.3.3 and sampling will start at the same time as the tracer injection. Once sampling is completed at TAN-25 and/or TAN-31 on Day 1, one of the sampling teams will purge and sample TAN-26. All samples will be analyzed as specified in Section A-3.4.

A-3.3.2 Sodium Lactate and Sodium Iodide Sampling

TAN-25 and TAN-31 will be purged prior to the tracer injection as specified in Section A-3.3.3 and sampling will start at the same time as the tracer injection at a frequency specified in Section A-3.3. Once sampling is completed at TAN-25 and TAN-31 every four or six minutes, the sampling teams will purge and sample TAN-26 and TAN-D2. One additional sample will then be taken at TAN-25 and TAN-31 as time allows. Locations TAN-37A, TAN-37B, and TAN-37C will subsequently be sampled as per the schedule in Table A-3-3. All samples will be analyzed as specified in Section A-3.4.

A-3.3.3 Well Purging

All wells will be purged prior to sample collection using the micropurge method, according to TPR-165, "Low Flow Groundwater Sampling Procedure." This applies to all groundwater sampling activities. The micropurge method was chosen due to waste management constraints and the need to have all applicable wells sampled within the same day, if possible. The needed equipment and purging procedure are provided in the technical procedures (TPRs). Dedicated pumps will be used in all wells. The target pumping rate will be 4 to 6 L/min (1 to 1 ½ gpm). The estimated amount of purge water generated from each well for each of the sampling activities is provided in Table A-3-4.

Table A-3-4. Well purge water volumes.

Well	Discharge Line Diameter (in.)	Length of Discharge Line[a] (ft)	Estimated Purge Volume[b] (gal)
TAN-25	1	218	27
TAN-26	1	389	48
TAN-31	1	258	32
TAN-D2	1	241	30
TAN-37A	0.5	250 (reel tubing length) 240 (pump depth)	8
TAN-37B	0.5	275	9
TAN-37C	1	379	46

a. Length of discharge line measured from the middle of the screened interval of the casing.
b. Purge water is calculated based on a maximum of three discharge line volumes.

The tracer test will require containers to manage the water produced from the purging of the wells listed in Table A-3-4. After the appropriate volumes in wells TAN-25 and TAN-31 have been purged, flowrates will be decreased to approximately 1.89 L/min (0.5 gpm), and pumping will be continuous while they are being sampled.

A-3.3.4 Water Level Monitoring

Water levels will be measured throughout the tracer tests using downhole transducers in wells TSF-05, TAN-25 and TAN-31. The transducers will be connected to dataloggers and readings stored at intervals of 15 minutes or less during the tracer and lactate injections. Water level responses to injections will be used to calibrate the numerical flow model.

A-3.3.5 In Situ Monitoring

Hydrolab Minisondes will be deployed in wells TAN-31, TAN-37A and TAN-37B throughout the tracer test. A Hydrolab CTD-Diver will be deployed in TAN-25. The Minisondes record temperature, specific conductance, pH, oxidation-reduction potential (ORP) and depth; and the CTD-Diver records specific conductance, temperature and depth. These instruments will be used to observe water quality variations throughout the tracer test.

A-3.4 Sample Analysis

Analyses of bromide, iodide, and COD will be performed in the field. The lactate, acetate, propionate, and butyrate analysis will be conducted at the INEEL Research Center (IRC). Concentrations of acetate, propionate, and butyrate will be analyzed by diluting the filtered sample with an equal volume of pH 2.5 deionized water and then directly injecting 1 μL into a HP Model 5890 Series II GC equipped with a FID, as described in the ISB FEWP Sampling and Analysis Plan (SAP) (Sorenson and Bullock 1999). Lactate concentrations will be determined in a filtered sample using a Dionex 4000I ion chromatograph with a conductivity detector, as described in the ISB FEWP SAP (Sorenson and Bullock 1999). Cooling of samples requiring 4°C preservation will be performed immediately upon sample collection. Coolers containing frozen reusable ice will be used to chill samples, as required. Sample bottles will be preserved prior to sample collection for those samples requiring chemical preservation. All field analyses will be performed per TPR-166, "ISB Field Analyses Procedure," and within 48 hours of sampling. A summary of the sample analyses for the 2002 Tracer Test are located in Table A-3-5.

Table A-3-5. Sample analyses.

Analytical Parameter	Preservation	Method	Precision
Bromide	N/A	Ion-specific electrode (ISE)	2%
Iodide	N/A	Ion-specific electrode (ISE)	2%
Chemical Oxygen Demand	Cool, 4°C and ratio of sample to H_2SO_4 must remain 9:1	Colorimetric	20%
Lactate	4°C	Ion Chromatography	10%
Acetate/Propionate/Butyrate	4°C	Gas chromatography/flame ionization detection (GC/FID)	10%

A-3.4.1 Radiological Screening

Samples collected from wells TAN-25, TAN-26, and TAN-31 will be surveyed for external radiological contamination prior to analysis. All other wells to be sampled have been historically free of radioactivity.

A-3.4.2 Chain-of-Custody

To maintain and document possession of samples shipped to the IRC for analysis, chain-of-custody (COC) procedures will be followed per MCP 3480, "Environmental Instructions for Facilities, Processes, Materials and Equipment" and the Quality Assurance Project Plan (QAPjP). The purpose of the COC is to document the identity of the sample and its handling from the point of collection until laboratory analysis is complete. When a sample changes custody, the person relinquishing and receiving the sample will sign a COC record. Each change of possession will be documented. The COC procedures will begin immediately after sample collection. The sample identification number, date, and time will be entered on the COC form the day of sample collection. Sample bottles will be stored in a secured area accessible only to the field team members. A COC will not be initiated for those samples that are analyzed onsite in the field laboratory. These samples will never leave the custody of the field team members.

A-3.4.3 Transportation of Samples

Appropriate samples will be packed in coolers with reusable ice and the COC and transported in a government vehicle to the IRC in accordance with the regulations issued by the Department of Transportation (49 Code of Federal Regulations [CFR] Parts 171 through 178) and EPA sample handling, packaging, and shipping methods (40 CFR 261.C.3C.3). All samples will be packaged in accordance with the requirements set forth in MCP 3480, "Environmental Instructions for Facilities, Processes, Materials and Equipment" and the governing task order statement.

A-3.5 Data Analysis and Reporting

Data will be analyzed using mathematical models. Mathematical models are used to represent complex processes such as groundwater flow and contaminant and tracer transport. Commonly, quantities simulated by the mathematical model such as head change or solute concentrations are more readily measured than are model input parameter values such as in-situ hydraulic conductivity, dispersivity, sorption, or contaminant decay. Model calibration is used to construct a model and estimate model parameter values. In model calibration, various parts of the model, including the value of model input parameters, are changed so that the measured values (often called observations) are matched by equivalent simulated values, until the resulting model is determined to represent important aspects of the actual system with sufficient accuracy.

Not surprisingly, formal methods have been developed that attempt to estimate input parameter values given some mathematically described process and a set of relevant observations. These methods are called inverse models, and they generally are limited to estimating input parameters as defined above. Thus, the terms "inverse modeling" and "parameter estimation" commonly are synonymous.

There are various approaches or techniques used in the parameter estimation or inverse modeling process. The simplest approach is to adjust the model input parameters by hand, run the model, compare the model output to measured or observed values, adjust the model parameters, and repeat the process until there is an "adequate" match between the model output and observations. Parameter estimation methods and codes have been developed and refined over the years that offer the potential of automating the input parameter estimation part of the calibration process. These codes run the model, compare the model results to observations, vary the model input parameters, rerun the model, and repeat the process until a mathematical objective function is optimized. The objective function is a measure of the fit between simulated values and observations. A typical objective function is the weighted least-squares regression between simulated and observed values. The nonlinear regression required by groundwater flow and transport model parameter estimation is iterative in that a sequence of parameter updates is calculated until the parameter values converge to the set that satisfies the objective function.

There are limitations, potential pitfalls, and requirements inherent in the automated parameter estimation process; primary among them is the need to provide several times more data points than parameter values to be estimated. A well-designed tracer test and a combination tracer test and electron donor injection are likely to be amenable to the nonlinear regression automated parameter estimation. The observations will be obtained as a time series, whereas the input parameter values are not expected to change with time and the number of useful observations can be expected to exceed the number of critical parameters by the required ratio.

The PEST and UCODE codes are available for the automated parameter estimation. Both can use a sequence of MODFLOW and MT3DMS runs to estimate the parameters of both models (if there are sufficient observations). The recently developed TAN OU 1-07B ISB groundwater flow and transport model (MODFLOW and MT3DMS codes) will be linked to PEST or UCODE in the parameter estimation process. Once the data is reduced and analyzed, the results will be reported in an Appendix of the FY 2002 Annual Report.

A-4. ENVIRONMENT, SAFETY, AND HEALTH; QUALITY; AND WASTE MANAGEMENT

A-4.1 Environment, Safety, and Health

The OU 1-07B Health and Safety Plan (HASP) (INEEL 2001a) establishes procedures and requirements that will be used for all activities associated with OU 1-07B. The major field activities for the 2002 Tracer Test period are tracer and lactate injection and groundwater sampling, as described in Section A-3. The OU 1-07B HASP includes a hazard assessment for all anticipated activities and specifies procedures and equipment to be used for worker safety. This HASP will be revised if conditions change sufficiently to require it.

A-4.2 Quality Assurance

This plan is intended to be used in conjunction with the QAPjP. Laboratory quality assurance (QA) for the tracer test includes running blanks, duplicates, standards, and standard additions (matrix spikes). Field QA includes field blanks and field duplicates. Procedures for preparing standards and standard additions are described in the equipment manufacturer's product information.

Minimum external and internal QA frequencies are specified in Tables A-4-1 and A-4-2, respectively. Precision and accuracy requirements for field laboratory analyses are cited in Table A-4-3, and are based on results to date reported in the ISB Annual Report for FY 2002 (INEEL 2002) and equipment manufacturer's specifications.

Blanks are run at varying frequencies for field laboratory parameters. No QA parameter is calculated, however non-zero results for blanks should be recorded and the cause determined by the field laboratory administrator.

Corrective actions will be performed when the precision and accuracy ranges specified in Table A-4-3 are exceeded. The laboratory technician and/or field laboratory lead will first repeat the analyses. If satisfactory results are obtained no further action is required. If results of the second analysis are outside the specified ranges the laboratory technician and/or field laboratory lead will troubleshoot the method to correct the problem, e.g., recalibrate, re-prepare the standard, etc. When the problem is corrected, the field laboratory lead will determine how many, if any, samples need to be re-analyzed (samples will be retained until the FLL has determined that the data quality and completeness are adequate). If the problem cannot be corrected, the field team lead and technical lead should be notified and the vendor contacted. Unsatisfactory results for field duplicates may indicate problems with the sampling procedures and troubleshooting should be coordinated with the FTL. Analyses should not be continued until the method produces results within the specified ranges, without direction from the technical lead.

Table A-4-1. External QA frequency for OU 1-07B ISB tracer test laboratory analyses.

Sample Type	Frequency
Field Duplicate	1 per 20 samples[a]
Field blank	1 per 20 samples[a]

a. For each analysis type per day samples are collected. If number of samples for a given analyte on a given day is less than 20, at least one QA sample will be collected.

Table A-4-2. Internal QA frequency for OU 1-07B ISB tracer test laboratory analyses.

QA Parameter	COD	Br^- and I^-
Precision		
Duplicates[a]	1/20 samples or 1/batch	1/20 samples
Accuracy		
Standards	1/20 samples or 1/batch	1/20 samples
Matrix spikes	N/A	1/well

a: Duplicates will not be collected during sampling at wells TAN-25 and TAN-31 on Day 1 and Day 2 due to the short sample intervals.

Table A-4-3. QA precision, accuracy, and completeness requirements for OU 1-07B ISB tracer test laboratory analyses.

QA Parameter	**COD**	**Br^- and I^-**
Precision		
Target RPD for duplicates[a]	Values $\leq$ 125 mg/L = 50%	10%
	Values > 125 mg/L = 25%	
Accuracy		
Target percent recovery for standards	90-110%	90-110%
Completeness[b]	90%	90%

a. Includes both field duplicates and internal lab duplicates.

b. Of those samples determined by the FLA to require analysis.

A-4.3 Waste Management

Listed waste will be generated at OU 1-07B as a result of sampling activities discussed herein. The types, disposition, and handling of listed waste that will be generated are discussed below.

The sampling activities described above will generate potentially contaminated wipes, sample bottles, personal protective equipment (i.e., gloves), and purge water. All of the solid materials will be bagged and labeled with the contents, waste code F001 for TCE, and identified as mixed waste. The waste will be transferred to the storage area for storage with Waste Stream 1935A.R1 under direction of Waste Generator Service (WGS) personnel. Volume estimates for the purge water generated during the 2002 Tracer Test are shown in Table A-4-4. Unaltered purge water will be transferred to the New Pump and Treat Facility (NPTF) surge tank for processing. To optimize the processing time at the NPTF, purge water from TAN-26 and TAN-D2, which can be processed at 2 gpm, will be segregated from the purge water from TAN-25, TAN-31, TAN-37A, TAN-37B, and TAN-37C, which can be processed at ½ gpm. Sample residue from field analysis will be disposed and managed per the hazardous waste determination for the *Waste Management Plan for Test Area North Final Groundwater Remediation, OU 1-07B* (INEEL 1999).

Table A-4-4. 2002 Tracer Test Purge Water Volume Estimate

	Number of times well is purged per day	Purge volume (gal)	Additional volume from continuous flow during sampling (gal)	Total Volume (gal)
Day 1				
TAN-25	1	27	225[a]	252
TAN-31	1	32	225[a]	257
TAN-26	1	48	0	48
Total				**557**
Day 2				
TAN-25	2	27	195[b]	249
TAN-31	2	32	195[b]	259
TAN-26	1	48	0	48
TAN-D2	1	30	0	30
Total				**586**
Day 3-5, Day 8-11				
TAN-26	2	48	0	96
TAN-D2	2	30	0	60
TAN-37A	2[c]	8	0	16
TAN-37B	2[c]	9	0	18
TAN-37C	2[c]	46	0	92
TAN-31	1	32	0	32
TAN-25	1	27	0	27
Total				**341**

a. Continuous pumping at 0.5 gal/min for 7.5 hours.
b. Continuous pumping at 0.5 gal/min for 6.5 hours.
c. Calculations based on the assumption that TAN-37A, TAN-37B, and TAN-37C are sampled twice per day.

A-5. BUDGET

The cost estimate for performing the 2002 Tracer Test is presented in Table A-5-1. These costs begin with the preparation of the work plan and go through the end of the tracer test and data analysis.

Table A-5-1. 2002 Tracer Test cost estimate.

Activity	FTEs	Resource	Rate, $/hr	Hours per FTE	Total cost, dollars	Comments
Work Plan (WP)						
Prepare WP	1	Env. Eng	$65.00	140	$9,100.00	
Project Review WP	4	Sr. Rev Team	$65.00	4	$1,040.00	
ORB Review WP	5	Env Eng	$65.00	4	$1,300.00	
Comment resolution	1	Env eng	$65.00	12	$780.00	
Technical oversight	1	PM	$70.00	20	$1,400.00	
Field Preparation						
	2	Env Eng	$65.00	40	$5,200.00	Inventory supplies, set-up and test ion specific probes, stage materials, final prep
	1	Field engineer	$65.00	20	$1,300.00	Stage tracer mixing and injection equipment, final prep
Technical oversight	1	Env Eng	$70.00	4	$280.00	
Materials	1	lot			$6,000.00	Probes, standards, tracer
Tracer Test						
Day 1 sampling and analysis	4	Field tech	$50.00	10	$2,000.00	Intensive sampling at TAN-25 and -31, one sampling of TAN-26 in PM
	2	Lab tech	$50.00	10	$1,000.00	
	1	Field lab lead	$60.00	10	$600.00	
	1	FTL	$60.00	10	$600.00	
	2	Field engineer	$65.00	10	$1,300.00	Process purge water

Table A-5–1. (continued).

Activity	FTEs	Resource	Rate, $/hr	Hours per FTE	Total cost, dollars	Comments
Days 2-7 sampling and analysis	2	Field tech	$50.00	60	$6,000.00	Sampling TAN-D2, -26, -37ABC
	1	Lab tech	$50.00	60	$3,000.00	
	1	Field lab admin	$60.00	60	$3,600.00	
	1	FTL	$60.00	60	$3,600.00	
	2	Field engineer	$65.00	10	$1,300.00	Process purge water
Data Analysis & Interpretation						
Data analysis	1	Env. Eng	$70.00	80	$5,600.00	
Technical oversight	1	PM	$70.00	8	$560.00	
Total				**632**	**$55,560.00**	

FTE = full-time employee
FTL = field team leader
PM = project manager

A-6. SCHEDULE

Table A-6-1 identifies the sample analyte and frequency for all sampling locations on each day of the 2002 Tracer Test. Table A-6-2 identifies the schedule for the tracer injections and subsequent sampling associated with the 2002 Tracer Test.

Table A-6-1. Sample location schedule

Location	July 29, 2002			
	Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	Every 4 minutes until <10% peak for 2 consecutive samples.	N/A	N/A	N/A
TAN-26[a]	Once	N/A	Once	N/A
TAN-31	Every 6 minutes until <10% peak for 2 consecutive samples.	N/A	N/A	N/A
TAN-37A	N/A	N/A	N/A	N/A
TAN-37B	N/A	N/A	N/A	N/A
TAN-37C	N/A	N/A	N/A	N/A
TAN-D2[a]	N/A	N/A	N/A	N/A
Injection Line	Every 1 minute during tracer injection	N/A	N/A	N/A
Location	**July 30, 2002**			
	Analyte/Sampling Frequency			
	Bromide	**Iodide**	**COD**	**VFAs**
TAN-25	N/A	Every 4 minutes until <10% peak for 2 consecutive samples/Once[b].	Every 4 minutes until <10% peak for 2 consecutive samples/Once[b].	Once[c]
TAN-26[a]	N/A	Once	Once	Once
TAN-31	N/A	Every 6 minutes until <10% peak for 2 consecutive samples/Once[b].	Every 6 minutes until <10% peak for 2 consecutive samples/Once[b].	Once[c]
TAN-37A	N/A	N/A	N/A	N/A
TAN-37B	N/A	N/A	N/A	N/A
TAN-37C	N/A	N/A	N/A	N/A
TAN-D2[a]	N/A	Once	Once	Once
Injection Line	N/A	Every 1 minute during tracer injection	N/A	N/A

Table A-6–1. (continued).

Location	July 31, 2002 Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	N/A	Once	Once	Once
TAN-26[a]	N/A	Twice	Twice	Twice
TAN-31	N/A	Once	Once	Once
TAN-37A	N/A	Once/Twice[d]	Once/Twice[d]	Once/Twice[d]
TAN-37B	N/A	Once/Twice[d]	Once/Twice[d]	Once/Twice[d]
TAN-37C	N/A	Once/Twice[d]	Once/Twice[d]	Once/Twice[d]
TAN-D2[a]	N/A	Twice	Twice	Twice
Injection Line	N/A	N/A	N/A	N/A
Location	August 1, 2002 Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	N/A	Once	Once	Once
TAN-26[a]	N/A	Twice	Twice	Twice
TAN-31	N/A	Once	Once	Once
TAN-37A	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37B	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37C	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-D2[a]	N/A	Twice	Twice	Twice
Injection Line	N/A	N/A	N/A	N/A
Location	August 2, 2002 Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	N/A	Once	Once	Once
TAN-26[a]	N/A	Twice	Twice	Twice
TAN-31	N/A	Once	Once	Once
TAN-37A	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37B	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37C	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-D2[a]	N/A	Twice	Twice	Twice
Injection Line	N/A	N/A	N/A	N/A
Location	August 3, 2002 Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	N/A	N/A	N/A	N/A
TAN-26[a]	N/A	N/A	N/A	N/A
TAN-31	N/A	N/A	N/A	N/A
TAN-37A	N/A	N/A	N/A	N/A
TAN-37B	N/A	N/A	N/A	N/A
TAN-37C	N/A	N/A	N/A	N/A
TAN-D2[a]	N/A	N/A	N/A	N/A
Injection Line	N/A	N/A	N/A	N/A

Table A-6–1. (continued).

Location	August 4, 2002			
	Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	N/A	N/A	N/A	N/A
TAN-26[a]	N/A	N/A	N/A	N/A
TAN-31	N/A	N/A	N/A	N/A
TAN-37A	N/A	N/A	N/A	N/A
TAN-37B	N/A	N/A	N/A	N/A
TAN-37C	N/A	N/A	N/A	N/A
TAN-D2[a]	N/A	N/A	N/A	N/A
Injection Line	N/A	N/A	N/A	N/A
Location	August 5, 2002			
	Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	N/A	Once	Once	Once
TAN-26[a]	N/A	Twice	Twice	Twice
TAN-31	N/A	Once	Once	Once
TAN-37A	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37B	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37C	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-D2[a]	N/A	Twice	Twice	Twice
Injection Line	N/A	N/A	N/A	N/A
Location	August 6, 2002			
	Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	N/A	Once	Once	Once
TAN-26[a]	N/A	Twice	Twice	Twice
TAN-31	N/A	Once	Once	Once
TAN-37A	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37B	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37C	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-D2[a]	N/A	Twice	Twice	Twice
Injection Line	N/A	N/A	N/A	N/A
Location	August 7, 2002			
	Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	N/A	Once	Once	Once
TAN-26[a]	N/A	Twice	Twice	Twice
TAN-31	N/A	Once	Once	Once
TAN-37A	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37B	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37C	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-D2[a]	N/A	Twice	Twice	Twice
Injection Line	N/A	N/A	N/A	N/A

Table A-6–1. (continued).

Location	August 8, 2002			
	Analyte/Sampling Frequency			
	Bromide	Iodide	COD	VFAs
TAN-25	N/A	Once	Once	Once
TAN-26[a]	N/A	Twice	Twice	Twice
TAN-31	N/A	Once	Once	Once
TAN-37A	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37B	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-37C	N/A	Once/Twice[d]	Once/Twice[d]	N/A
TAN-D2[a]	N/A	Twice	Twice	Twice
Injection Line	N/A	N/A	N/A	N/A

VFA = volatile fatty acid

a. Sampling will be discontinued if COD concentration declines to less than 10% of the peak value for two consecutive samples.

b. Once sampling is discontinued every 4 or 6 minutes, a sample will be taken at TAN-26 on Day 1 and TAN-26 and TAN-D2 on Day 2. TAN-25 and TAN-31 will then be sampled once more as time allows.

c. As time allows.

d. Once iodide is detected at TAN-26 and/or TAN-D2, then TAN-37A, TAN-37B, and TAN-37C will be sampled twice daily.

Table A-6-2. 2002 Tracer Test Schedule.

Activity	Date	Duration or sampling interval (min)	Time
Site walkdown/Prejob brief	7/25/2002	NA	N/A
Day 1	[redacted]		
POD meeting	7/29/2002	30	7:00 AM
Set Hydrolab DO	7/29/2002	30	7:30 AM
Purging TAN-25 and -31	7/29/2002	27, 32	8:00 AM
Bromide tracer injection	7/29/2002	30	8:32 AM
Sampling at TAN-25 and -31	7/29/2002	Every 4 or 6 minutes[a]	8:32 AM
Sampling at injection line	7/29/2002	Every 1 minute during bromide injection	8:32 AM
Sample Team 1 Lunch	7/29/2002	30	11:00 AM
Sample Team 2 Lunch	7/29/2002	30	11:30 AM
Purge TAN-26	7/29/2002	48	4:00 PM
Sample TAN-26	7/29/2002	5	4:48 PM

Table A-6–2. (continued).

Activity	Date	Duration or sampling interval (min)	Time
Day 2			
POD meeting	7/30/2002	30	7:00 AM
Set Hydrolab DO	7/30/2002	30	7:30 AM
Purging TAN-25 and -31	7/30/2002	27, 32	8:00 AM
Lactate and iodide injection	7/30/2002	Iodide – 30 Lactate – ongoing	8:32 AM
Sampling at TAN-25 and -31	7/30/2002	Every 4 or 6 minutes[b]	8:32 AM
Sampling at injection line	7/30/2002	Every 1 minute during iodide injection	8:32 AM
Sample Team 1 Lunch	7/30/2002	30	11:00 AM
Sample Team 2 Lunch	7/30/2002	30	11:30 AM
Purge TAN-26	7/30/2002	48	3:30 PM
Sample TAN-26	7/30/2002	5	4:18 PM
Purge TAN-D2	7/30/2002	30	3:30 PM
Sample TAN-D2	7/30/2002	5	4:00 PM
Purge TAN-31[c]	7/30/2002	32	4:20 PM
Sample TAN-31[c]	7/30/2002	5	4:52 PM
Purge TAN-25[c]	7/30/2002	27	4:38 PM
Sample TAN-25[c]	7/30/2002	5	5:05 PM
Day 3[d]			
POD meeting	7/31/2002	30	7:00 AM
Set Hydrolab DO	7/31/2002	30	7:30 AM
Purge TAN-26	7/31/2002	48	8:00 AM
Sample TAN-26	7/31/2002	5	8:48 AM
Purge TAN-D2	7/31/2002	30	9:15 AM
Sample TAN-D2	7/31/2002	5	9:45 AM

Table A-6–2. (continued).

Activity	Date	Duration or sampling interval (min)	Time
Purge TAN-37A	7/31/2002	8	10:10 AM
Sample TAN-37A	7/31/2002	5	10:18 AM
Purge TAN-37B	7/31/2002	9	10:23 AM
Sample TAN-37B	7/31/2002	5	10:32 AM
Purge TAN-37C	7/31/2002	46	10:37 AM
Sample TAN-37C	7/31/2002	5	11:23 AM
Sample Team 1 Lunch	7/31/2002	30	11:30 AM
Purge TAN-31	7/31/2002	32	12:00 PM
Sample TAN-31	7/31/2002	5	12:32 PM
Purge TAN-25	7/31/2002	27	12:52 PM
Sample TAN-25	7/31/2002	5	1:19 PM
Purge TAN-26	7/31/2002	48	1:39 PM
Sample TAN-26	7/31/2002	5	2:27 PM
Purge TAN-D2	7/31/2002	30	2:47 PM
Sample TAN-D2	7/31/2002	5	3:17 PM
Purge TAN-37A[e]	7/31/2002	8	3:37 PM
Sample TAN-37A[e]	7/31/2002	5	3:45 PM
Purge TAN-37B[e]	7/31/2002	9	3:50 PM
Sample TAN-37B[e]	7/31/2002	5	3:59 PM
Purge TAN-37C[e]	7/31/2002	46	4:04 PM
Sample TAN-37C[e]	7/31/2002	5	4:50 PM
Day 4[d]	[redacted]		
POD meeting	8/01/2002	30	7:00 AM
Set Hydrolab DO	8/01/2002	30	7:30 AM
Purge TAN-26	8/01/2002	48	8:00 AM
Sample TAN-26	8/01/2002	5	8:48 AM

Table A-6–2. (continued).

Activity	Date	Duration or sampling interval (min)	Time
Purge TAN-D2	8/01/2002	30	9:15 AM
Sample TAN-D2	8/01/2002	5	9:45 AM
Purge TAN-37A	8/01/2002	8	10:10 AM
Sample TAN-37A	8/01/2002	5	10:18 AM
Purge TAN-37B	8/01/2002	9	10:23 AM
Sample TAN-37B	8/01/2002	5	10:32 AM
Purge TAN-37C	8/01/2002	46	10:37 AM
Sample TAN-37C	8/01/2002	5	11:23 AM
Sample Team 1 Lunch	8/01/2002	30	11:30 AM
Purge TAN-31	8/01/2002	32	12:00 PM
Sample TAN-31	8/01/2002	5	12:32 PM
Purge TAN-25	8/01/2002	27	12:52 PM
Sample TAN-25	8/01/2002	5	1:19 PM
Purge TAN-26	8/01/2002	48	1:39 PM
Sample TAN-26	8/01/2002	5	2:27 PM
Purge TAN-D2	8/01/2002	30	2:47 PM
Sample TAN-D2	8/01/2002	5	3:17 PM
Purge TAN-37A[e]	8/01/2002	8	3:37 PM
Sample TAN-37A[e]	8/01/2002	5	3:45 PM
Purge TAN-37B[e]	8/01/2002	9	3:50 PM
Sample TAN-37B[e]	8/01/2002	5	3:59 PM
Purge TAN-37C[e]	8/01/2002	46	4:04 PM
Sample TAN-37C[e]	8/01/2002	5	4:50 PM
Day 5[d]	[redacted]		
POD meeting	8/02/2002	30	7:00 AM
Set Hydrolab DO	8/02/2002	30	7:30 AM

Table A-6–2. (continued).

Activity	Date	Duration or sampling interval (min)	Time
Purge TAN-26	8/02/2002	48	8:00 AM
Sample TAN-26	8/02/2002	5	8:48 AM
Purge TAN-D2	8/02/2002	30	9:15 AM
Sample TAN-D2	8/02/2002	5	9:45 AM
Purge TAN-37A	8/02/2002	8	10:10 AM
Sample TAN-37A	8/02/2002	5	10:18 AM
Purge TAN-37B	8/02/2002	9	10:23 AM
Sample TAN-37B	8/02/2002	5	10:32 AM
Purge TAN-37C	8/02/2002	46	10:37 AM
Sample TAN-37C	8/02/2002	5	11:23 AM
Sample Team 1 Lunch	8/02/2002	30	11:30 AM
Purge TAN-31	8/02/2002	32	12:00 PM
Sample TAN-31	8/02/2002	5	12:32 PM
Purge TAN-25	8/02/2002	27	12:52 PM
Sample TAN-25	8/02/2002	5	1:19 PM
Purge TAN-26	8/02/2002	48	1:39 PM
Sample TAN-26	8/02/2002	5	2:27 PM
Purge TAN-D2	8/02/2002	30	2:47 PM
Sample TAN-D2	8/02/2002	5	3:17 PM
Purge TAN-37A[e]	8/02/2002	8	3:37 PM
Sample TAN-37A[e]	8/02/2002	5	3:45 PM
Purge TAN-37B[e]	8/02/2002	9	3:50 PM
Sample TAN-37B[e]	8/02/2002	5	3:59 PM
Purge TAN-37C[e]	8/02/2002	46	4:04 PM

Table A-6–2. (continued).

Activity	Date	Duration or sampling interval (min)	Time
Sample TAN-37C[e]	8/02/2002	5	4:50 PM
Day 6	8/03/2002	No Sampling	
Day 7	8/04/2002	No Sampling	
Day 8[d]	[redacted]		
POD meeting	8/05/2002	30	7:00 AM
Set Hydrolab DO	8/05/2002	30	7:30 AM
Purge TAN-26	8/05/2002	48	8:00 AM
Sample TAN-26	8/05/2002	5	8:48 AM
Purge TAN-D2	8/05/2002	30	9:15 AM
Sample TAN-D2	8/05/2002	5	9:45 AM
Purge TAN-37A	8/05/2002	8	10:10 AM
Sample TAN-37A	8/05/2002	5	10:18 AM
Purge TAN-37B	8/05/2002	9	10:23 AM
Sample TAN-37B	8/05/2002	5	10:32 AM
Purge TAN-37C	8/05/2002	46	10:37 AM
Sample TAN-37C	8/05/2002	5	11:23 AM
Sample Team 1 Lunch	8/05/2002	30	11:30 AM
Purge TAN-31	8/05/2002	32	12:00 PM
Sample TAN-31	8/05/2002	5	12:32 PM
Purge TAN-25	8/05/2002	27	12:52 PM
Sample TAN-25	8/05/2002	5	1:19 PM
Purge TAN-26	8/05/2002	48	1:39 PM
Sample TAN-26	8/05/2002	5	2:27 PM
Purge TAN-D2	8/05/2002	30	2:47 PM
Sample TAN-D2	8/05/2002	5	3:17 PM
Purge TAN-37A[e]	8/05/2002	8	3:37 PM

Table A-6–2. (continued).

Activity	Date	Duration or sampling interval (min)	Time
Sample TAN-37A[e]	8/05/2002	5	3:45 PM
Purge TAN-37B[e]	8/05/2002	9	3:50 PM
Sample TAN-37B[e]	8/05/2002	5	3:59 PM
Purge TAN-37C[e]	8/05/2002	46	4:04 PM
Sample TAN-37C[e]	8/05/2002	5	4:50 PM
Day 9[d]	[redacted]		
POD meeting	8/06/2002	30	7:00 AM
Set Hydrolab DO	8/06/2002	30	7:30 AM
Purge TAN-26	8/06/2002	48	8:00 AM
Sample TAN-26	8/06/2002	5	8:48 AM
Purge TAN-D2	8/06/2002	30	9:15 AM
Sample TAN-D2	8/06/2002	5	9:45 AM
Purge TAN-37A	8/06/2002	8	10:10 AM
Sample TAN-37A	8/06/2002	5	10:18 AM
Purge TAN-37B	8/06/2002	9	10:23 AM
Sample TAN-37B	8/06/2002	5	10:32 AM
Purge TAN-37C	8/06/2002	46	10:37 AM
Sample TAN-37C	8/06/2002	5	11:23 AM
Sample Team 1 Lunch	8/06/2002	30	11:30 AM
Purge TAN-31	8/06/2002	32	12:00 PM
Sample TAN-31	8/06/2002	5	12:32 PM
Purge TAN-25	8/06/2002	27	12:52 PM
Sample TAN-25	8/06/2002	5	1:19 PM
Purge TAN-26	8/06/2002	48	1:39 PM
Sample TAN-26	8/06/2002	5	2:27 PM
Purge TAN-D2	8/06/2002	30	2:47 PM

Table A-6–2. (continued).

Activity	Date	Duration or sampling interval (min)	Time
Sample TAN-D2	8/06/2002	5	3:17 PM
Purge TAN-37A[e]	8/06/2002	8	3:37 PM
Sample TAN-37A[e]	8/06/2002	5	3:45 PM
Purge TAN-37B[e]	8/06/2002	9	3:50 PM
Sample TAN-37B[e]	8/06/2002	5	3:59 PM
Purge TAN-37C[e]	8/06/2002	46	4:04 PM
Sample TAN-37C[e]	8/06/2002	5	4:50 PM
Day 10[d]	[redacted]		
POD meeting	8/07/2002	30	7:00 AM
Set Hydrolab DO	8/07/2002	30	7:30 AM
Purge TAN-26	8/07/2002	48	8:00 AM
Sample TAN-26	8/07/2002	5	8:48 AM
Purge TAN-D2	8/07/2002	30	9:15 AM
Sample TAN-D2	8/07/2002	5	9:45 AM
Purge TAN-37A	8/07/2002	8	10:10 AM
Sample TAN-37A	8/07/2002	5	10:18 AM
Purge TAN-37B	8/07/2002	9	10:23 AM
Sample TAN-37B	8/07/2002	5	10:32 AM
Purge TAN-37C	8/07/2002	46	10:37 AM
Sample TAN-37C	8/07/2002	5	11:23 AM
Sample Team 1 Lunch	8/07/2002	30	11:30 AM
Purge TAN-31	8/07/2002	32	12:00 PM
Sample TAN-31	8/07/2002	5	12:32 PM
Purge TAN-25	8/07/2002	27	12:52 PM
Sample TAN-25	8/07/2002	5	1:19 PM
Purge TAN-26	8/07/2002	48	1:39 PM

Table A-6–2. (continued).

Activity	Date	Duration or sampling interval (min)	Time
Sample TAN-26	8/07/2002	5	2:27 PM
Purge TAN-D2	8/07/2002	30	2:47 PM
Sample TAN-D2	8/07/2002	5	3:17 PM
Purge TAN-37A[e]	8/07/2002	8	3:37 PM
Sample TAN-37A[e]	8/07/2002	5	3:45 PM
Purge TAN-37B[e]	8/07/2002	9	3:50 PM
Sample TAN-37B[e]	8/07/2002	5	3:59 PM
Purge TAN-37C[e]	8/07/2002	46	4:04 PM
Sample TAN-37C[e]	8/07/2002	5	4:50 PM
Day 11[d]	[redacted]		
POD meeting	8/08/2002	30	7:00 AM
Set Hydrolab DO	8/08/2002	30	7:30 AM
Purge TAN-26	8/08/2002	48	8:00 AM
Sample TAN-26	8/08/2002	5	8:48 AM
Purge TAN-D2	8/08/2002	30	9:15 AM
Sample TAN-D2	8/08/2002	5	9:45 AM
Purge TAN-37A	8/08/2002	8	10:10 AM
Sample TAN-37A	8/08/2002	5	10:18 AM
Purge TAN-37B	8/08/2002	9	10:23 AM
Sample TAN-37B	8/08/2002	5	10:32 AM
Purge TAN-37C	8/08/2002	46	10:37 AM
Sample TAN-37C	8/08/2002	5	11:23 AM
Sample Team 1 Lunch	8/08/2002	30	11:30 AM
Purge TAN-31	8/08/2002	32	12:00 PM
Sample TAN-31	8/08/2002	5	12:32 PM
Purge TAN-25	8/08/2002	27	12:52 PM

Table A-6–2. (continued).

Activity	Date	Duration or sampling interval (min)	Time
Sample TAN-25	8/08/2002	5	1:19 PM
Purge TAN-26	8/08/2002	48	1:39 PM
Sample TAN-26	8/08/2002	5	2:27 PM
Purge TAN-D2	8/08/2002	30	2:47 PM
Sample TAN-D2	8/08/2002	5	3:17 PM
Purge TAN-37A[e]	8/08/2002	8	3:37 PM
Sample TAN-37A[e]	8/08/2002	5	3:45 PM
Purge TAN-37B[e]	8/08/2002	9	3:50 PM
Sample TAN-37B[e]	8/08/2002	5	3:59 PM
Purge TAN-37C[e]	8/08/2002	46	4:04 PM
Sample TAN-37C[e]	8/08/2002	5	4:50 PM

a. Sampling will be discontinued when the concentration of the tracer at the well declines to less than 10% of the peak value for two consecutive samples or until 4:00 p.m.

b. Sampling will be discontinued every 4 (TAN-25) or 6 (TAN-31) minutes when the concentration of tracer at the well declines to less than 10% of the peak value for two consecutive samples or until 3:00 p.m.

c. As time allows

d. Discontinue sampling at TAN-26 and/or TAN-D2 if COD concentrations have declined to less than 10% of the peak value for two consecutive samples. Once iodide tracer is detected at TAN-26 and/or TAN-31, then the schedule will include sampling at TAN-37A, TAN-37B, and TAN-37C twice per day.

e. Disregard this schedule event unless iodide tracer has been detected at TAN-26 and/or TAN-D2.

A-7. CALCULATIONS AND TRACER MIXING PROCEDURE

Calculations used to determine tracer solution injection flowrates are included in Section A-7.1. The tracer solutions will be prepared according to the mixing procedures in Sections A-7.2.

A-7.1 Tracer Concentration and Injection Calculations

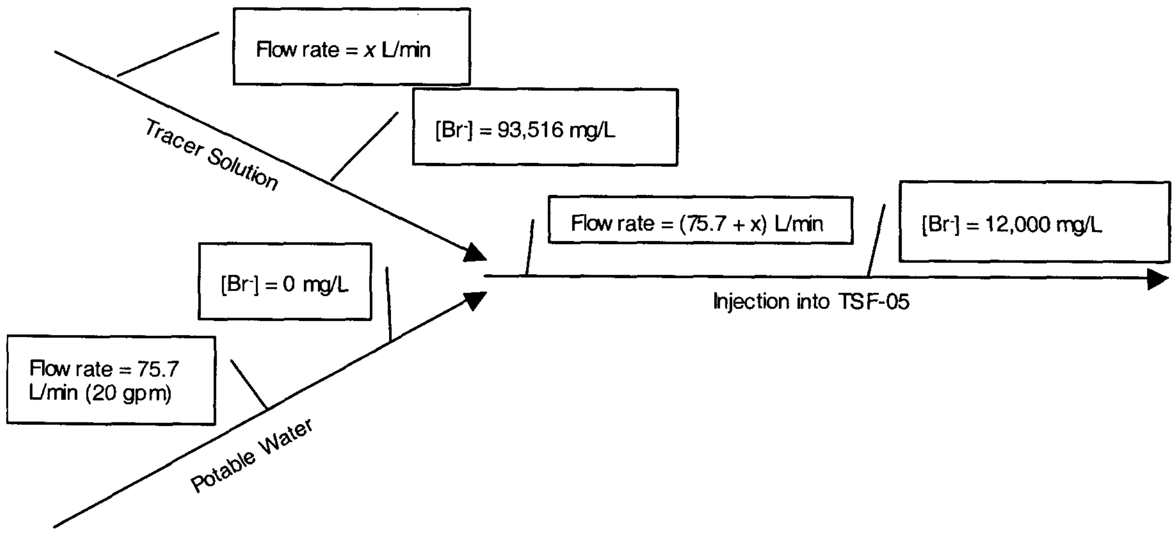
A-7.1.1 Sodium Bromide Tracer Solution Calculations

Assumptions/Knowns:

1. 36 kg of NaBr is mixed with potable water to make a total volume of 79 gal (299 L)
2. Desired [Br^-] into TSF-05 is 12,000 mg/L
3. Solubility of NaBr is 733,000 mg/L @ 20°C
4. Flowrate for potable water is 75.7 L/min (20 gpm)

$$\frac{36{,}000{,}000\ mg\ NaBr}{299\ L} = 120{,}400\ mg\ NaBr\ per\ liter$$

$$120{,}400\ mg\ NaBr \ \bullet\ \frac{80\ g\ Br^-\ per\ mole}{80+23\ g\ NaBr\ per\ mole} = \underline{93{,}516\ mg\ Br^-\ per\ liter} \leftarrow \underline{[Br^-]\ in\ tracer\ solution}$$



$$93{,}516\ mg\,/\,L\ \bullet\ x\ L\,/\min = 93{,}516x\ mg\,/\min$$

$$\frac{93{,}516x\ mg/\min}{(75.7+x)\ L/\min} = 12{,}000\ mg/L$$

$$93{,}516x = 908{,}400 + 12{,}000x$$

$$81{,}516x = 908{,}400$$

$$\underline{\underline{x = 11.1\ L/min\ (3.0\ gal/min)}} \longleftarrow \text{Tracer solution flowrate required for 12,000 mg Br}^-\text{/L into TSF-05}$$

Time required to pump tracer solution: $\dfrac{79\ gal}{3.0\ gal/\min} = 26.3\ \min$

Total volume injected into TSF-05: $86.8\ L/\min \bullet 26.3\ \min = \underline{\underline{2283\ L\ (603\ gal)}} \xleftarrow{\text{Total Volume Injected}}$

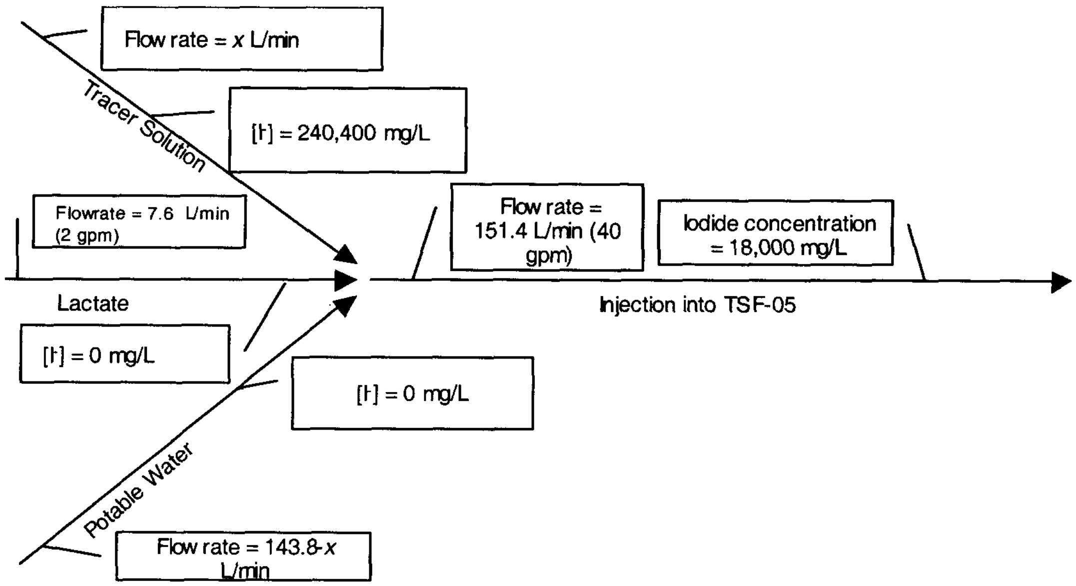
A-7.1.2 Sodium Iodide Tracer Calculations

Assumptions/Knowns:

1. 72 kg of NaI is mixed with potable water to make a total volume of 67 gal (253.6 L)
2. Desired [I^-] into TSF-05 is 18,000 mg/L.
3. Solubility of NaI is 1,840,000 mg/L @ 25°C
4. Flowrate of the sodium lactate is 7.6 L/min (2 gpm), Flowrate for the tracer solution and potable water is ~143.8 L/min (38 gpm)

$$\frac{72{,}000{,}000\ mg\ NaI}{253.6\ L} = 284{,}000\ mg\ NaI\ per\ liter$$

$$284{,}000\ mg\ NaI \bullet \frac{127\ g\ I^-\ per\ mole}{127+23\ g\ NaI\ per\ mole} = \underline{240{,}400\ mg\ I^-\ per\ liter} \xleftarrow{[I^-]\text{ in tracer solution}}$$



$$240{,}400\ mg/L \bullet x\ L/\min = 240{,}400x\ mg/\min$$

$$\frac{240{,}400x\ mg/\min}{151.4\ L/\min} = 18{,}000\ mg/L$$

$240{,}400x = 2{,}725{,}200$

Tracer solution flowrate required for 18,000 mg I⁻/L into TSF-05

$\underline{\underline{x = 11.3 \text{ L/min } (3.0 \text{ gpm})}}$ ←

Potable water flowrate required for 18,000 mg I⁻/L into TSF-05

$143.8 - x = \underline{132.5 \text{ L/min } (35 \text{ gpm})}$ ←

Time required to pump tracer solution: $\dfrac{67\ gal}{3\ gal/\min} = 22.3 \min$

Total volume injected into TSF-05:

$$151.4\ L/\min \bullet 22.3 \min = \underline{\underline{3376\,L\ (892\ gal)}}$$ ← *Total Volume Injected*

A-7.2 Tracer Mixing Procedure

Both tracer solutions will be prepared in four 55-gal drums according to the outline below.

1. Inspect the four 55-gal drums for cleanliness and integrity

2. Measure the amount of tracer chemical required (25 kg and 11 kg of NaBr or 59 kg and 13 kg of NaI)

3. Fill the drums that will contain 55 gal of tracer solution with approximately 25 gal of potable water (1/2 full); fill the remaining two drums with 24 gal and 12 gal of potable water respectively

4. Place the tracer chemicals in the drum (25 kg of NaBr in ½ full drum, 11 kg of NaBr in drum filled with 24 gal; 59 kg of NaI in ½ full drum, 13 kg of NaI in drum filled with 12 gal); attach labels that describe contents of each drum

5. Insert both the inlet end and the fluid outlet end of a drum pump into the drum

6. Switch the drum pump to the ON position and allow the tracer solution to mix for 15 minutes (through recirculation)

7. After mixing is complete, switch the drum pump to the OFF position and remove the pump from the drum

8. Fill the remainder of the ½ full drums to 55 gal with potable water

9. Switch the drum pump to the ON position and allow the tracer solution to mix with the additional potable water for 15 minutes (through recirculation) and close lids tightly.

A-8. REFERENCES

Arnett, June 2002, *TAN OU 1-07B ISB Groundwater Model Development and Initial Performance Simulation,* INEEL/EXT-02-00560, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Cohen R.M. and J.W. Mercer, February 1993, *DNAPL Site Evaluation,* EPA/600/R-93/022, U.S. Environmental Protection Agency.

DOE-ID, September 1998, *Enhanced In Situ Bioremediation Field Evaluation Work Plan, Test Area North, Operable Unit 1-07B,* DOE/ID-10639, Revision 0, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho.

DOE-ID, September 2001, *Record of Decision (ROD) Amendment - Technical Support Facility Injection Well TSF-05 And Surrounding Groundwater Contamination TSF-23 And Miscellaneous No Action Sites, Final Remedial Action (Ra),* DOE/ID-10139, Amendment Rev. 0, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho.

EPA, 1994, *Data Quality Objectives Process for Superfund, Interim Final Guidance,* EPA 540-R-93-071, U.S. Environmental Protection Agency.

IDEQ, 1998, Letter from Hazardous Waste Permitting Bureau Chief B.R. Monson to LMITCO Deputy Director of Environmental Affairs C.R. Koshuta, September 17, 1998, Idaho Department of Environmental Quality.

INEEL, April 1999, *Waste Management Plan for Test Area North Final Groundwater Remediation, OU 1-07B,* INEEL/EXT-98-00267, Revision 1, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

INEEL, July 2000, *Field Evaluation Report of Enhanced In Situ Bioremediation, Test Area North, Operable Unit 1-07B,* INEEL/EXT-2000-00258, Revision 0, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

INEEL, April 2001a, *Test Area North Operable Unit 1-07B Final Groundwater Remedial Action Health and Safety Plan,* INEEL/EXT-99-00020, Revision 1, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

INEEL, May 2001b, *Sampling and Analysis Plan for Enhanced In Situ Bioremediation Predesign Operations Test Area North, Operable Unit 1-07B,* INEEL/EXT-2000-00925, Revision 1, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

INEEL, March 2002, *Operable Unit 1-07B In Situ Bioremediation Annual Performance Report for October 1999 to July 2001,* INEEL/EXT-2002-00543, Revision 0, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

MCP 3480, "Environmental Instructions for Facilities, Processes, Materials and Equipment," Revision 7, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Sorenson, K.S. and H. Bullock, 1999, *Sampling and Analysis Plan for the Enhanced In Situ Bioremediation Field Evaluation Test Area North, Operable Unit 1-07B,* INEEL/EXT-98-00421, Revision 1, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

TPR-163, "Nutrient Injection System Operating Procedure," Revision 4, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

TPR-165, "Low Flow Groundwater Sampling Procedure," Revision 5, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

TPR-166, "ISB Field Analyses Procedure," Revision 4, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Wymore, R.A., J.M. Bukowski, and K.S. Sorenson, Jr., December 2000, *Site Conceptual Model: 1998 and 1999 Activities, Data Analysis, and Interpretation for Test Area North, Operable Unit 1-07B,* INEEL/EXT-2000-00188, Revision 0, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.